PB-233 117

DEVELOPMENT OF PREDICTIONS OF FUTURE POLLUTION PROBLEMS

James E. Flinn, et al

Battelle Columbus Laboratories

Prepared for:

Environmental Protection Agency

March 1974

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

J

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

1. Report No.
2.

PB 233 117
W
74-08946

4. Title
Development of Predictions of Future Pollution Problems,

5. Report Date
6\.
8. Performing Organization Report No.

7. Author(s)
J~~ames~~ E. Flinn and R~~obert~~ S. Reimers

9. Organization
Battelle-Columbus Laboratories, Ohio

EPA Program Element 1HA095
Contract 68-01-1837

13. Type of Report and Period Covered

12. Sponsoring Organization

Socioeconomic Studies Series
Environmental Protection Agency, report ~~number,~~
EPA-600/5-74-005, March 1974. 207p, 7 fig, 41 tab.

16. Abstract

The report describes the results of a program to identify, rank and project short- and intermediate-term future pollution problems.

Identification was accomplished using three independent search approaches based on industrial production, environmental, and societal trends and activity. Primary emphasis was placed on the environmental trends as gleaned from EPA, Battelle, literature, and other sources. An initial list of problems was compiled with specific stressors identified with each.

Nine ranking factors were devised to select ten "most serious" problems from the initial list. The factors included: persistence; mobility/pervasiveness; environmental, technological, social, and political complexity; physiological risk; research needs; and bulk or volume of the pollutant. The ten problems selected by this method were further ranked in order of relative importance. The ten selected problems in rank order are as follows:

1. Impacts of New Energy Initiatives;
2. Geophysical Modifications of the Earth;
3. Trace Element (Metal) Contaminants,
4. Proliferating Hazardous and Toxic Chemicals;
5. Emissions from New Automobile Fuels, Additives, and Control Devices;
6. Disposal of Waste Sludges, Liquids, and Solid Residues;
7. Critical Radiation Problems;
8. Fine Particulates;
9. Expanding Drinking Water Contamination; and
10. Irrigation (Impoundment) Practices.

Five to ten year projections were made of the ten problems which resulted. (EPA)

17a. *Pollutants, Pollutant Identification, Air Pollution, *Water Pollution, sources, Strip mines, *Forecasting, Land use

17b. Identifiers
*Future Pollution Problems, ~~Land Use~~, Mine Pollution, Toxic Chemicals, Fine particulates, Radiation Problems.

17c. COWRR Field & Group 05 B, 05G

Copy Available from GPO Sup Doc as EP 1.23: 600/5-74-005, $ 2.40; microfiche from NTIS as PB $1.45

18. Availability

19. Security Class. (Report)
20. Security Class. (Page)

21. No. of Pages
22. Price

Send To:

WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U S DEPARTMENT OF THE INTERIOR
WASHINGTON D C 20240

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

I

EPA-600/5-74-005
March 1974

DEVELOPMENT OF PREDICTIONS OF FUTURE POLLUTION PROBLEMS

by

James E. Flinn and Robert S. Reimers

Contract No. 68-01-1837
(Program Element 1HA095)

Project Officer

James R. Hibbs
IMPLEMENTATION RESEARCH DIVISION
WASHINGTON ENVIRONMENTAL RESEARCH CENTER
Washington, D. C. 20460

Prepared for
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D. C. 20460

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $2.40

EPA REVIEW NOTICE

This report has been reviewed by the Office of Research and Development, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of tradenames or commercial products constitute endorsement or recommendations for use.

FORWARD

This report presents the results of an effort to identify and project the magnitude of short- to intermediate- term pollution problems. The research was undertaken at the request of the then Deputy Administrator of the Environmental Protection Agency, Mr. Robert Fri, for the purpose of aiding Agency program planning. The work was performed by Battelle Columbus Laboratories under contract from the Ecological Studies and Technology Assessment Branch, Implementation Research Division, Washington Environmental Research Center. We wish to thank Drs. James R. Hibbs and Harold V. Kibby of EPA for their outstanding efforts in this project and the authors and the Battelle Columbus staff for their cooperation in meeting our requirements in a timely fashion.

E B Royce
Edwin B. Royce, Ph.D.
Chief, Ecological Studies and
Technology Assessment Branch

Alan Carlin
Alan P. Carlin, Ph.D.
Director, Implementation
Research Division

ABSTRACT

The report describes the results of a program to identify, rank and project short- and intermediate-term future pollution problems.

Identification was accomplished using three independent search approaches based on industrial production, environmental, and societal trends and activity. Primary emphasis was placed on the environmental trends as gleaned from EPA, Battelle, literature, and other sources. An initial list of problems was compiled with specific stressors identified with each.

Nine ranking factors were devised to select ten "most serious" problems from the initial list. The factors included: persistence; mobility/pervasiveness; environmental, technological, social, and political complexity; physiological risk; research needs; and bulk or volume of the pollutant. The ten problems selected by this method were further ranked in order of relative importance. The ten selected problems in rank order are as follows.

Impacts of New Energy Initiatives
Geophysical Modifications of the Earth
Trace Element (Metal) Contaminants
Proliferating Hazardous and Toxic Chemicals
Emissions from New Automobile Fuels, Additives, and Control Devices
Disposal of Waste Sludges, Liquids, and Solid Residues
Critical Radiation Problems
Fine Particulates
Expanding Drinking Water Contamination
Irrigation (Impoundment) Practices.

Five to ten year projections were made of the ten problems which resulted.

This report was submitted in fulfillment of Contract No. 68-01-1837 under the sponsorship of the Office of Research and Monitoring, Environmental Protection Agency.

Preceding page blank

CONTENTS

Section		Page
I	Conclusions	1
II	Recommendations	4
III	Introduction	5
IV	Impacts of New Energy Initiatives	9
V	Geophysical Modification of the Earth	21
VI	Trace Elements (Metal) Contaminants	32
VII	Proliferating Hazardous and Toxic Chemicals	45
VIII	Emissions from New Automotive Fuels, Additives, and Control Devices	53
IX	Disposal of Waste Sludges, Liquids, and Solid Residues	66
X	Critical Radiation Problems	76
XI	Fine Particulates	94
XII	Expanded Drinking Water Contamination	107
XIII	Irrigation (Impoundment) Practices	116
XIV	Acknowledgments	132
XV	Appendices	
	A. Identification of Candidate Problems	A-1
	B. Selection of Most Serious Problems	B-1

Preceding page blank

FIGURES

Page

1 Pollution Chain Diagram for the Environmental Stressor Lead 34

2 Geographical Distribution of Pesticide-Caused Fish Kills 1963-1968 49

3 Threshold Levels Versus Time for Three Sensitive Structures 87

4 Irrigated Land in the United States 117

5 Time and Temperature Effects Upon Oxygen Content (SAG) in Free-Flowing and Impounded Rivers 128

6 Salinity in Parts Per Thousand and Number of Fish Species in the Laguna Tamaulipas, Mexico, During 1961 through 1965 129

7 Saturation Values of Dissolved Oxygen Versus Salinity 129

Preceding page blank

TABLES

No.		Page
1	U.S. Energy Outlook, 1971 to 1985	11
2	Range of Oil Imports (Million bbl/day)	14
3	National Summary of Petroleum Tanker Traffic Density Forecasts	14
4	Type of Material Discharged for 1971 (U.S. Coast Guard)	17
5	Annual Spill Volumes at Various Oil Import Levels (barrels)	17
6	Trace Element Concentrations (mg/l) in Smelter-Refinery Effluents	35
7	Elemental Air Emissions from U.S. Production and Consumption Operations--tons/year	37
8	Projected Air Emissions of Selected Elements	38
9	Heavy Metal Concentrations in Selected Sludge Samples (ppm on dry basis)	40
10	Fish Kills Resulting from Pesticides	48
11	Annual Production of Air Pollution in Millions Tons/Year	54
12	Itemization of the Automobile Totals Including Quantities Replaced and Net Additions from 1950 Extrapolated to 2000	55
13	A List and Prediction of Total Mileage, Gasoline Usage, and Total Registered Automobiles from 1950 to 2000	57
14	Summary of Exhuast Emission Standards for Light-Duty Vehicles	58
15	Relative Quantities of Potential Lead Substitutes	60
16	Aromatic Levels in Gasoline Resulting from Staged Lead Removal	60
17	Total Quantity of Catalytic Convertors Needed by Weight and the Weight of Trace Metals Adsorbed	63
18	Average Sludge Quantities in Municipal Wastewater Treatment	68
19	Residential Microwave Oven Installations	78

Preceding page blank

TABLES
(Continued)

No.		Page
20	Total Broadcast Stations in U.S.	81
21	Maximum Observed Power Density Levels in Four Biologically Relevant Frequency Bands	84
22	Total Power Densities Over Radio and Television Bands (for Site Number 1, Holy Cross Hospital)	84
23	Total Power Densities Over Entire Frequency Range for Each of 10 Sites	85
24	Sources and Quantities of Mercury Emission	98
25	Sources and Quantities of Beryllium Emission	99
26	Sources and Quantities of Asbestos Emission	100
27	Sources and Quantities of Lead Emission	101
28	Sources and Quantities of Cadmium Emission	102
29	Sources and Quantities of POM Emission	103
30	Projections of Fine Particulate Emission from Industrial Sources	105
31	Municipal Water Supply in the U.S. (1960-1980)	108
32	United States: Estimated Water Use, 1900-1975	118
33	Acres of Irrigated Land, Inputs and Outputs of Water and Salt for Irrigated Land from 1957 to 1964 for Coachella Valley, California	120
34	Salt Balance, Yakima Valley, Washington	121
35	Comparison of Irrigation Water and Drainage Water, Yakima Valley, Washington	123
36	Incremental Salt Concentration Attributable to Specific Sources, Colorado River at Hoover Dam	124
37	Probable Fate of Municipal and Industrial Pollutants after Irrigation	125

TABLES
(Continued)

No.		Page
38	Trace Element Tolerances for Irrigation Waters	126
A-1	Preliminary List of Problems by Area and Title	A-5
B-1	Problem Statement Rankings	B-5
B-2	List of Ranked Statements	B-6

SECTION I

CONCLUSIONS

Conclusions are presented under three headings as follows: Identification, Ranking, and Projections.

Identification

The framework employed to screen candidate problems was generally effective. The major barrier to completeness was the short time period (5 weeks) allowable in this program for the search. Nevertheless, it was quite possible to screen many more problems than actually were selected for inclusion in the initial list.

Ranking

The nine ranking factors employed for selecting 10 most serious problems proved to be useful tools. The major difficulty in applying these to the candidate problems was their lack of preciseness relative to necessarily broad problem statements. Nevertheless, it is felt that these tools helped considerably to avoid totally subjective and biased judgements.

Projections

Examination of the magnitude and effects of selected aspects of the ten most serious problems identified has led to the following set of conclusions.

(1) As a consequence of an expected near doubling of energy demand within the next ten years, increased

quantities of spilled oil from tanker ship operations can be anticipated, especially in the period up to 1980.

(2) Adverse environmental, ecological, and socioeconomic effects are a common consequence of many large-scale engineering efforts aimed at extraction and transport of minerals, fossil fuels, and natural resources. Examples examined include coal mining, stream channel modifications, and oil and gas pipeline construction. More detailed knowledge of the effects are needed to adequately evaluate alternative ways of providing man's material and energy needs.

(3) Elucidation of sources, pathways, and health effects associated with trace element contaminants from production-consumption (principally metallurgical) processes, municipal wastewater treatment and other sources is a major near-term problem. A greater knowledge of health effects will aid in selection of acceptable control options.

(4) Sources, pathways and effects of toxic and hazardous chemicals (primarily organics) require serious study. Pesticides as a class are a particularly major problem with complex social, economic, and political consequences. Systematic methods of making before-the-fact screening and selection of specific problem chemicals for health-effects testing are needed.

(5) The secondary effects on the environment incurred through technology changes necessary to meet legislated automotive exhaust control deadlines require examination. New fuel compositions and additives and the use of catalysts for HC and CO control may bring new exhaust pollutants to the foreground.

(6) Ultimate disposal practice with respect to (1) residues

from pollution control systems and (2) polluting low value, large volume solid and liquid residues from established production sectors needs to be defined. Acceptable options are quite limited in certain locations (population centers, etc.).

(7) An increased exposure of the general population to radio frequency radiation is apparent over the next 5 years and beyond. Low-level (nonthermal) effects from radiation sources for heating, detection, communications and power transmission are not known.

(8) Research on improved control systems for removing fine particulates from air (those that now evade capture by currently used technology) is needed. Health effects due to inhalation and trapping of same are felt to be serious.

(9) A complete reassessment is needed of drinking water standards, treatment technology, and supply in view of the recognition that ever-increasing quantities of toxic organic and inorganic pollutants are entering water supply sources.

(10) Irrigation, as a practice to meet agricultural and land development needs in arid regions of the U.S., has been increasing at a rate of better than 2 billion gal/day since 1960. The effects of this practice require more study along with alternative measures for their control or mitigation.

SECTION II

RECOMMENDATIONS

The following recommendations are made based on the work accomplished.

(1) A continuing systematic effort to identify serious national, regional, or local pollution problems and pollutants, including the possibility of developing a formalized alerting network.

(2) Greater effort relative to such a continuing search should be spent exploring industry and government sources (other than EPA and Battelle) for candidate problems.

(3) Continued development and refinement of screening and ranking parameters which are essential for making factual (as opposed to subjective) selections of most serious problems.

(4) Development of a formalized panel of experts (of various backgrounds and associations) to aid in evaluating candidate problems.

(5) A possible conference on future environmental problems open to professionals in all fields. Such problems are likely being recognized now in connection with R&D on environmental topics now being funded by EPA and other agencies.

(6) Review of EPA budgeting priorities with respect to the ten problem areas identified in this work.

SECTION III

INTRODUCTION

There is a need for early identification of environmental problems so that resources for corrective and control measures can be identified and developed before-the-fact. Indicators of such problems do exist, although systematic application of them for this need has not been attempted on any large scale by EPA.

This program was initiated as a preliminary effort to identify short (5 year) and intermediate term (10 year) pollution problems (in the U.S.) which would be useful for EPA program planning needs. The general approach employed was to screen three broad categories of human activity with the objective of identifying major future trends which adversely impact on man or his environment. The three categories which formed the starting point for study were:

(1) Sectors of Technical Production Activity
(2) Sectors of Environmental Concern
(3) Sectors of Societal Change and/or Trends.

These three sectors were screened over a several week period employing a variety of methods such as (1) interviews with knowledgeable Battelle and EPA resource personnel, (2) group discussions, and (3) literature sources. The preliminary list of identified problems developed (given in Appendix A) was screened to select ten for further analysis. Ranking factors were defined (Appendix B) to aid in making the selection. These were supplemented by the application of professional judgment and discussion with EPA personnel acquainted with the program. The resulting list of ten problems was examined in more detail to quantify, where possible, likely environmental consequences over the next 5-year period. Three of the 10 problems were selected, based on further ranking efforts, for a similar 10-year analysis.

In the course of the work many problem areas were reviewed, ranging over (1) specific compounds [e.g., hexachlorobenzene], (2) classes of substances [e.g., fluorocarbons], (3) processes [production, consumption, disposal, etc.] yielding emissions to air, water, or land, (4) activities [construction, aerial spraying, pollution control] with associated adverse environmental effects, and (5) natural conditions which contribute to contamination of the environment [volcanos, wind, solar radiation]. The category screening approach was effective in the sense that (1) a framework was provided wherein an essentially unlimited reservoir of potential problems could be systematically rapidly sifted, (2) many significant problems were identified, and (3) findings from the technical production and societal change category searches tended to reinforce and substantiate those from the environmental concern category.

Time limitations for compilation and ranking of the initial list of candidate problems--about 5 weeks total--and the broad scope of activity sectors from whence the candidates were derived, precluded more than a cursory review of the three categories studied. Similar considerations restricted the depth to which an identified problem could be assessed during both the process of selecting the ten "most serious" and the subsequent efforts at projection of magnitude and effects for these. Consequently, the authors make no claim for completeness. Some significant problems were missed, in fact, during preparation of the initial candidate list. Those that did subsequently come to the attention of the project staff could not retroactively be incorporated into the selection process. The remaining program time and funds necessarily had to be focused on developing information on the magnitude and effects of the ten selected problems. It is further recognized that too little effort has been spent on (1) interviews with persons outside of EPA and Battelle, (2) examination of the social, political, and economic aspects of identified problems, (3) in depth analysis of information sources to ascertain if the data and trends were valid (for example - is there a real energy crisis) and (4) imaginative conception of solutions to the problems. Nevertheless, the resulting ten most serious problems are felt to be significant problems of the near future and of national importance.

It is evident that a continuing systematic effort at searching for problems is needed, and that such an effort could be conducted on an international, national, regional, or local basis with considerable benefit to EPA.

Projections of Magnitude and Effects

Sections IV through XIII which will follow are brief topical reports on selected aspects of the ten problems identified--arranged in the order of the final ranking.

It should be apparent from the titles that, in most instances, the problems identified are quite broad in scope. This is a natural consequence of aggregating related problems with the objective of defining a problem of national as opposed to regional or local importance, since EPA's overall budget priorities are surely assigned on that basis. In attempting to project future magnitude and effects, one could not hope to deal in any detail with all facets of such general problem areas. Where necessary, some judgment was therefore applied to select one or at the most two facets for more detailed examination. However, even this proved difficult to do in some cases (e.g., trace element contaminants). The factors used in deciding what facet to project included (1) whether the facet in question was, in fact, a near- or short-term future problem requiring a solution; (2) the extent to which the facet is or had been examined already by current scientific, social, and political institutions (e.g., radioactive substances associated with nuclear power have received intensive scrutiny by the Atomic Energy Commission); and (3) whether it merited attention as a national problem (a subjective judgment, obviously, at this point in the program).

It is informative to examine the group of 10 problems in toto, since there are some commonalities and interrelationships which in themselves suggest areas where R&D priorities could be placed.

Section XII on drinking water contamination is a good case in point. Virtually every one of the other nine problem areas impact on man's need for and use of water for drinking purposes. This is because water perhaps more than air becomes a receptor for nearly all pollutants to some degree. Likewise, though "trace element contaminants" (Section VI) is defined as a distinct problem, pollution of the environment from automobiles, energy production, waste residues, pesticides, air emissions, etc., all contribute to it. Only a few of the problem pairs appear independent of one another and with some detailed study a relationship could likely be found. These include

(1) New Energy Initiatives and Irrigation Practices*

(2) Geophysical Modifications and Automobile Emissions

(3) Automobile Emissions and Radiation

(4) Automobile Emissions and Irrigation Practices.

One feature which is common to most, if not all, of these problems is their multimedia nature. The transfer of pollutants from one medium to another is now a well recognized phenomena. For specific pollutants such as trace metals and other hazardous organic or inorganic chemicals the extent to which this has occurred in the past is fairly well documented. The adoption of pollution-control measures, resulting from environmental legislation, is a contributor to intermedia transfer. Study of the nature, extent and effects of intermedia pollutant transfers could well be a high-priority area itself for environmental R&D.

The need for more information on sources, pathways and effects, especially health effects, of stressors is an aspect common to several of the problems identified. Similarly, the impact of specific stressors on ecosystems, while recognized, needs clarification in order that tradeoffs between man's material needs and environmental controls can be balanced.

---

* May be coupled in the future by the need for cooling water in power plants located in arid regions.

SECTION IV

IMPACTS OF NEW ENERGY INITIATIVES

Nature of Problem

Current concern exists over the possibility of shortages over the next 5-10 years in energy resources. This concern is popularly referred to as the "energy crisis". Whether the crisis is due to actual resource limitations or the effects of institutional policies of the past (more probable), one fact appears fairly certain, viz., the energy demand of the U.S. is expected to nearly double between now and 1985. Meeting this demand will require major technological efforts, all having significant environmental impacts. The development of new energy technologies such as coal gasification, coal liquefaction, oil shale and tar sand processes, and nuclear reactors, are at an early stage. The impact of these will likely not be fully felt until a time greater than 10 years in the future. It is logical to examine these developments now with respect to likely environmental effects and incorporate controls as the technology develops. And, in fact, this is already being done as a consequence of increased public awareness of environmental issues.

Of more importance are the short-term pollution problems that will arise as a result of certain initiatives being instituted today in anticipation of meeting actual energy and environmental needs within the next ten-year period. These problems include: (1) oil spill incidents from current and projected massive imports of foreign oil; (2) radioactive emissions and waste disposal needs from increased numbers of nuclear power installations; and (3) increasingly large volumes of solid residues from coal cleaning--needed to help meet SO_x emission limitations on coal powered electric plants. Of these three problems, only oil spill incidents will be projected here. The problems of radiation effects and disposal of pollution control residues from nuclear power production and coal cleaning are covered elsewhere. The environmental effects of coal gasification, oil shale, and other emerging technologies lie farther into the future than this program is aiming and it is assumed that their associated environmental consequences will be dealt with as the technology develops.

Projection

Energy Needs and Sources

U.S. energy needs in 1985 are expected to about double - from 68 quadrillion Btu in 1970 to 125 quadrillion Btu in 1985.(1)* Four major sources of energy are available: oil, gas, coal, and nuclear. Table 1, from National Petroleum Council data, indicates the extent to which these four sources are projected to share the market in 1985 compared to 1971. Note that hydroelectric power, geothermal, oil shale, and coal liquids and gases are expected to contribute only a few percent to 1985 needs.

Natural gas is already in short supply. With some imports and production of synthetics the current level of gas availability can be maintained. However, by 1985 natural gas will have only half of its current share of the energy market. Imports of natural gas in 1972 totaled 1,032 billion cubic feet - a 1.04 percent increase over 1971.(2)

Coal exists in abundant supply in the U.S. It is the major fuel used for generating electric power. In 1972, electric utilities accounted for 65.6 percent of all coal consumed.(2) About half of the electric power generated in the U.S. is based on coal. Even though a trend has existed toward substitution of low-sulfur fuel oils for coal by utilities, the demand for coal by utilities will increase significantly in the next 10 years due to a shortage of liquid fuels. Physical cleaning of coal to reduce sulfur contents appears to be the only alternative currently to avoid the higher economic cost of fuel oil.

---

* References appear at the end of each Section.

TABLE 1. U.S. ENERGY OUTLOOK, 1971 TO 1985(1)

Energy Source	Percent of Total Energy for 1971	Percent of Total Energy for 1985
Liquid Fuels	44	44
Coal	18	18
Natural Gas	33	17
Hydropower	4	2.5
Nuclear	less than 1	greater than 17
Geothermal	Negligible	less than 0.5
Synthetic Gas from Coal	0	0.75
Synthetic Liquids from Oil Shale	0	0.2
Synthetic Liquids from Coal	0	0

Note: Data constrained by cost and projected current technology pace considerations.

According to the National Petroleum Council, meeting 1985 demands for liquid fuels could require importation from foreign sources of up to 65 percent of U.S. oil needs and up to 28 percent of its natural gas. Actually, in 1972, the U.S. imported a record 798.2 million barrels of crude oil, a 30.1 percent increase over 1971. In 1972 energy produced from imported fuels accounted for 12.5 percent of the total U.S. energy consumption.(2) The time factor needed to stem this tide of imported fuels is unknown. Apparently adequate reserves of recoverable oil and gas exist in the U.S., so that given favorable economic incentives the industry output could be substantially increased over its current level. Federal action in response to the projected balance-of-payments deficit may alter the current situation. On the assumption that the large import expectations will be achieved, it is possible to project a significant and potentially serious impact due to oil spills from tanker operations and accidents. Environmental impacts can also be expected from the construction of superports for large oil tankers.

Nuclear power is expected to supply 17 percent of U.S. energy needs in 1985. If reliable, this represents a substantial increase from the present and suggests certain environmental consequences-thermal water pollution, land disposal, or storage needs for high and low level radioactive wastes and increased emissions of radioactive substances to air and water media. Much study has already been given to these impacts by AEC and others as a result of the Federal National Environmental Policy Act (NEPA) requirements.

Any slippage of the projected nuclear power installation schedule will have a significant effect on the other energy sources, e.g., greater use of coal and oil in fossil fueled power plants constructed (in lieu of nuclear) to meet the demand. The projected nuclear capacity of 1985 amounts to 300 gigawatts of power.(1,3) The same amount of power from several fossil fuels would be as follows:

- 4.5 billion bbl/yr residual fuel oil

or
- 1100 million tons/yr of coal

or
- 76 trillion cu ft/yr of gas.

Three Future Problems

From the foregoing discussion, three specific future pollution problems can be identified:

(1) Large scale imports of petroleum and natural gas appear to be a fair possibility. The quantities involved will have environmental implication from the standpoint of spills in U.S. coastal and inland areas, and from the need to construct new facilities for large tankers.

(2) The growth of nuclear power, even if less than expected, will introduce problems of radioactive emissions via air and water routes, disposal of high and low level radioactive waste to the land, and possibly thermal water pollution effects.

(3) The need for coal resources to supply much of the 1985 energy demand is apparent, even with some switching by utilities to residual fuel oil. Significant incremental environmental effects are likely due to increased mining and physical coal cleaning for sulfur reduction purposes. Acid mine drainage and large volumes of coal residues are to be expected.

Oil Spill Quantities and Effects

Table 2 shows the projected quantities of oil imports needed to make up the U.S. energy deficit.(1) The worst and best estimates developed by the National Petroleum Council are given. The bulk of the needed imports would come by tankers into U.S. ports. Considerable expansion of facilities to handle the growing shipments is already underway. Environmental impact studies of superports - facilities for docking and off-loading oil from very large tanker fleets - are already underway.

TABLE 2. RANGE OF OIL IMPORTS (Million bbl/day)

Case*	1970	1975	1980	1985
Best	3.4	7.2	5.8	3.6
Worst	3.4	9.7	16.4	19.2

* Best case: Results from maximum effort to develop domestic fuel sources.

Worst case: Results from continuation of present trends in U.S. oil and gas drilling, i.e., continued deterioration of U.S. energy supply posture.

TABLE 3. NATIONAL SUMMARY OF PETROLEUM TANKER TRAFFIC DENSITY FORECASTS*(4)
(Tanker trips/year)

Region	Case A No Superport Operations			Case B Atlantic and Gulf Coast Superports		
	1975	1980	1985	1975	1980	1985
Atlantic Coast	9,170	12,365	10,837	9,170	10,272	8,496
Gulf Coast	3,687	5,397	5,872	3,687	8,267	6,565
Great Lakes	580	608	632	580	608	632
Pacific Coast	1,765	2,972	2,941	1,765	2,972	2,941
Alaska	485	2,589	2,642	485	2,589	2,642
Hawaii	142	125	125	142	125	125
Total United States	15,829	24,056	23,049	15,829	24,833	21,401

* Petroleum includes crude petroleum, gasoline, distillate fuel oil, and residual fuel oil.

The increase in tanker traffic into and out of U.S. ports has been recently estimated(4) and projected (Table 3). For the two cases shown - with and without superports - the peak year of 1980 shows upwards of 25,000 foreign and domestic tanker movements into and out of U.S. ports for the four commodities studied, a significant increase over 1975. The Atlantic and Gulf Coast areas are the most affected.

Table 4 shows the number and volume of spills of oil and other substances reported to the U.S. Coast Guard in 1971. The major percentage of these spills are categorized as light, heavy, or other oil. The data do not accurately define the types of oil. Most of this data probably resulted from ship operations rather than accidents from grounding or collision, since the 1967 Torrey Canyon incident alone, e.g., released 20,000,000 gallons of oil into the sea and another 20,000,000 gallons in the ship was burned to prevent release.(6)

The question of future spills, due to increased port traffic density resulting from accelerated oil imports, has been addressed by the Coast Guard in connection with recent proposed legislation on establishment and regulation of deepwater port facilities.(7) Several possibilities exist for shipment modes into U.S. ports. These include:

(1) Shipment direct to U.S. ports via tankers in the 50,000-70,000 DWT* size (no superport).

(2) Delivery by supertankers (~250,000 DWT) to U.S. deepwater ports located less than 50 miles offshore with
  (a) transshipment by pipeline to shore facilities, or
  (b) transshipment by smaller tankers to shore ports.

Another possibility is delivery in supertankers to non-U.S. Western Hemisphere deepwater ports in the Caribbean or Canadian Maritime Provinces with transshipment in small tankers to the U.S.--this is analogous to (1) above. The projected spill probabilities depend upon the mode actually employed. In fact, if mode 2a were employed a significant environmental impact from dredging of the needed deepwater port and transfer pipelines would result in lieu of fewer spill incidents. Complete transshipment from offshore superports is also analogous to the first mode.

---

* DWT - dead weight tons.

Methodology developed by the Coast Guard(7) has been employed to estimate annual incremental spill volumes in U.S. coastal areas as a function of oil import level. Results are given in Table 5 for three levels of daily oil imports. Using the worst case data of Table 2, and the data trends of Table 5, approximately 800,000 bbl of oil would be spilled in U.S. coastal and harbor zones within the next 10 year period (1973-1983) due to the increased oil imports in the absence of superports. Insofar that superports come into existence within this period, the amount would be expected to decrease, unless all of the oil is transshipped from offshore superports in tankers rather than by pipeline. The Coast Guard methodology is based on statistical analysis of 10 years of past accidental spill incident history (1960-1970)(7) as a function of spill volume.

Effects

Spills of oil cause a number of adverse effects in the environment not all of which are well understood. Oil and toxic components of the oil can be lethal to organisms or inhibit normal feeding or reproductive behavior as can coating of water fowl with oil. The coating of rocks, beaches, marshes, etc., can cause significant plant and organism mortality. Estuaries and nearshore coastal wetlands are the most biologically productive areas of the marine ecosystem and also the most sensitive to damage from oil spills.

Wave action causes some of the crude and residual oils to emulsify with the water; the unemulsified fraction spreads to form a slick about 0.001 inch thick in about a day. If the slick is not recovered, it is lost by dissolution and biodegradation. The thin slick on the surface does not last more than a week, but water-in-oil emulsions persist for several months.

Most crude and residual oils contain surfactants which promote the formation of a water-in-oil emulsion. These emulsions contain up to 80 percent water and because of the contained water are about the same density as seawater. The emulsions persist for months. While the emulsions

TABLE 4. TYPE OF MATERIAL DISCHARGED FOR 1971
(U.S. Coast Guard)

	Number of Incidents	Percent of Total	Gallons	Percent of Total
Light Oil (gasoline, light fuel oil, kerosene, light crude)	4,320	49.5	2,822,463	31.9
Heavy Oil (diesel oil, heating oil, heavy fuel oil, heavy crude, asphalt)	1,603	18.4	2,934,181	33.2
Lubricating Oil	168	1.9	22,365	0.3
Animal or Vegetable Oil	39	0.4	18,957	0.2
Waste Oil	930	10.6	164,352	1.9
Other Oil	462	5.3	2,673,077	30.2
Miscellaneous Materials (sewage, refuse, dredge spoil, etc.)	1,214	13.9	204,128	1.3
Total	8,736	100.0	8,839,523	100.0

TABLE 5. ANNUAL SPILL VOLUMES AT VARIOUS OIL IMPORT LEVELS (barrels)

Import Level (million bbl/day)	Case I No Superports	Case II Superports*
3	15,900	3,400
6	32,600	6,500
9	49,400	10,000
Average number of bbl spilled per million bbl/day imported	5,400	1,100

* With transshipment by pipeline.

are easy to pick up because they form thick ropes and do not disperse, the volume collected is greatly increased over the volume of oil. The emulsions are stiff and difficult to pump. Since they do not spread rapidly, they can be picked up long after the spill. However, their stability makes them a problem if they are not recovered. Most beach damage is caused by persistent emulsions of this type.

The seriousness of local damage will vary greatly depending upon where the spill occurs and will be reflected in the cost of cleanup and reparation of damage to private property. Little is known about the long term effects of oil in the marine environment. The most urgent immediate concern is to prevent its reaching shorelines and beaches where localized damage and costly cleanup can develop. In shallow-water enclosed lakes and embayments, and especially in flooded marshes, the problems are more serious. Slower tidal exchanges and smaller volumes of water tend to prolong the ill effects and to intensify the pollution per unit of oil lost.

Cleanup procedures following accidental oil spills can be more damaging to the environment than the oil pollution itself. Public reaction when accidents happen, coupled with the need to protect life, has precipitated the liberal use of dispersants and emulsifying chemicals to hasten the dissipation of visible oil. For the following reasons, such procedures utilizing currently available chemicals may be much more damaging to the aquatic ecosystem than less toxic but unsightly oil.(7,8)

(1) Detergents or dispersant chemicals may cause the oil to adsorb on mud and silt particles, which sink to the substrate or float in the water column where they are more available to filter feeders.

(2) Oil adsorbed on bottom particles appear to take longer to degrade.

(3) The use of chemicals to disperse the oil involves placing an additional load of foreign and undesirable material in the aquatic ecosystem. Many of the dispersants tested proved to be far more toxic than oil.

(4) Dispersal of oil inhibits the proper mapping and study of polluted areas.

Control Options

Multi-agency programs (Coast Guard, Navy, EPA, NOAA, etc.) on oil spill prevention, control, mitigation, and restoration are underway. Oil spill cooperatives are being established by major oil companies and regional authorities. Future control efforts should emphasize

(1) Reduction in spill volumes by preventing or minimizing casualties from collisions, grounding, rammings, etc., in high traffic density areas and operational mishaps from equipment failures, human error, and poor housekeeping

(2) Research and development on oil spill effects, control techniques and measures, spill identification measures, and spill data collection and analysis.

(3) The development of contingency plans and spill cleanup systems for high density traffic areas.

References

(1) National Petroleum Council, U.S. Energy Outlook - Report to NPC's Committee on U.S. Energy Outlook (December, 1972).

(2) "1972 Energy Use Continued Upward", News Release, Bureau of Mines (March 10, 1973).

(3) Davis, W. Kenneth, Environmental Challenges and Nuclear Fuels, Chemical Engineering Progress, 69 (6), 48-53 (June, 1973).

(4) Battelle's Columbus Laboratories, "Support Systems to Deliver and Maintain Oil Recovery Systems and Dispose of Recovered Oil" (June 8, 1973).

(5) Anonymous, "Polluting Incidents in and Around U.S. Waters, Calendar Year 1971", U.S. Coast Guard, Washington, D.C. (1972).

(6) Keith, V. F., "An Analysis of Oil Outflows due to Tanker Accidents", Proceedings of Joint Conference on Prevention and Control of Oil Spills, U.S. Coast Guard, Washington, D.C. (1972).

(7) Train, R. E., "Statement to House Committee on Public Works" (June 20, 1973).

(8) St. Amant, Lyle S., "The Petroleum Industry as It Affects Marine and Estuarine Ecology", Trans., Society of Petroleum Engineers Meeting (1971).

(9) St. Amant, Lyle, S., "Impacts of Oil on the Gulf Coast", Trans., North American Wildlife Conference (1971), to be published.

SECTION V

GEOPHYSICAL MODIFICATION OF THE EARTH

Nature of the Problem

In attempting to supply a growing demand for both renewable and nonrenewable natural resources, man resorts to a variety of technological measures which often have serious and widescale effects on the environment. Examples include (1) the use of underground nuclear explosions to release natural gas supplies, (2) strip mining for coal and mineral ores, (3) dredging to create deepwater ports for oil-bearing supertankers, (4) stream channel modifications, (5) ocean floor mining, (6) oil and gas pipeline construction, (7) silviculture practices, (8) deforestation and (9) the construction of dams for flood control, irrigation, and power production. In each case, major physical disturbances of the earth are made frequently over large land areas. These disturbances often cause such immediate and long lasting ecological and sometimes irreparable effects as: mine drainage, erosion, release of toxic substances, unsightly and nonproductive terrain, species eradication, etc. So long as man seeks to upgrade his standard of living, the demand for materials and energy will continue. In many areas of the U.S. this demand is in direct conflict with man's need for agricultural, recreational, industrial, and other uses of land and water resources. The problem is to find ways of providing these needs while at the same time minimizing the impact of the technological activity involved.

While it is not possible in the context of this study to examine in detail the magnitude and effects of the range of geophysical disturbances noted, it is instructive to focus on several examples which constitute near term problems from the standpoint of currently expanding activities. Thus the major impacts of mining--primarily coal mining--channeling and pipeline construction will be examined.

Projection

Mining

In 1972, approximately 50 percent of the 625 million tons of coal mined in the U.S. came from underground mines. A 5 percent growth per annum is projected for this mode of coal recovery. Problems of health and safety of workers (coal dust, air supply), getting coal to the surface, and acid mine drainage are prevalent.

The recovery of coal by surface or strip mining continues to grow. By 1965 an estimated 1.3 million acres of land in the U.S. had been disturbed by strip mining, a figure suggestive of the magnitude of the problem. A sharp jump in new acreage disturbed by strip mining occurred between 1969-1970. The increase, amounting to 25,000 acres, equaled the increase from the previous four years (1965-1969). In 1970, 100,000 acres were strip mined.(1) Montana, New Mexico, and Wyoming have important coal reserves available by surface mining techniques. Strip mining of low sulfur coal in the West is expected to increase sharply in the near future to meet the growing energy needs of that part of the country. Attempts are being made by some citizen groups to outlaw this production mode on the basis of environmental factors--esthetics, ecological upsets due to siltation of streams and acid drainage. There are currently no Federal regulations for land restoration of strip mined land although hearings on such legislation have been held. State regulations do exist. The replacement of ground cover (top soil and replanting) does provide a means of mine drainage control. The economics of doing so have not encouraged universal adoption of this practice.

In a recent study for EPA,(2) Battelle estimated the volume of acid mine drainage produced in 1970 from bituminous coal mines of the Appalachian mining region as 103.8 billion gallons. In that year, 294 million tons of bituminous coal were mined in the region. National Petroleum Council predictions for coal demand indicate an increase of 70-100 percent in demand (worst and best case) for coal by 1983.(3) Assuming mining of bituminous coal in the Appalachian regions grows accordingly, the amount of acid mine drainage there would nearly double to 200 billion gallons in 10 years if no preventative measures are taken. Another source has estimated 500 billion gallons of mine drainage in the Appalachian region, containing 5-10 million tons of acid and polluting over 10,000 miles of surface streams and 15,000 acres of impoundments.(4) When extended to all of the U.S and expanded to include strip mining as well, the amount of acid mine drainage from these souces is indeed enormous.

According to Reid and Streebin(5), although the complexities involved with acid mine drainage are controversial, there is general agreement as to the overall cause-effect relationship. The primary pollutants found in coal mine drainage are sulfuric acid, iron, trace metals (such as copper, cadmium, mercury, arsenic, lead, manganese, and zinc) and sediment. The formation of acid mine drainage stems from water of surface quality entering a mine and coming in contact with iron disulfide from rock strata and coal seams. In the presence of oxygen, ferrous sulfate and sulfuric acid form, lowering the pH; this allows other compounds containing Al, Mg. Mn, and Ca to be dissolved. Further contact with oxygen causes oxidation of ferrous to ferric sulfate and hydroxide, both of which are soluble at the low pH (2-4). In some instances, the natural ecology of the land will partially neutralize discharges within and around mine sites. The acidic discharges make the water corrosive and unfit for industrial use and recreation, contribute to destruction of aquatic life in streams, react with alkaline substances in the earth thus adding to the hardness of water, and are responsible for the deposition of some precipitants which affect the esthetics of a watercourse. One report indicated that, in 1967, over a million fish were killed in the U.S. as a result of acid mine drainage.(6)

Among the methods that have been or are being developed to alleviate the acid mine water pollution problem are: neutralization processes, reverse osmosis, ion exchange treatment, deep well disposal, acid formation inhibition by antibacterial action, and the electrolytic oxidation of ferrous iron with recovery of hydrogen. Neutralization is the best known and the one which has the most actual practice. Reverse osmosis has been extensively studied and appears to be a good candidate for further development and demonstration. Disposal of the resulting brine concentrate is a problem. Electrolytic oxidation of ferrous iron with recovery of hydrogen has been studied by EPA for treatment of acid mine waters. However, although the methods and technology have been developed, meeting the financial burden will be the major hurdle in alleviating mine water pollution in the future.(7)

The treatment of acid mine water results in the addition of dissolved solids to the water and the generation of a sludge for disposal. $CaSO_4$ is formed during treatment with limestone. This material has some water solubility (>2,000 ppm), a fact which restricts the way in which it can be disposed. (See discussion in related problem on wastes from pollution control activities.) Depending upon how the sludge is formed and handled, very large volumes require disposal (approximately 16 lbs/lb of sulfur).

One possible alternative to the mining of coal underground with its attendant worker health and safety problems is the process of in situ underground gasification. However, even though the Bureau of Mines may meet with initial success in developing this technology within the next few years, this effort probably will not lead to any commercial ventures until 1985.

Restoration of strip mined areas require grading, replacement of top soil and reestablishment of vegetation. Restoration, widely practiced in other countries,(8) can prevent much of the acid mine drainage associated with strip mining in the U.S.

Channel Modification

A recently issued study(9) prepared for the Council on Environmental Quality analyzes the dimensions of environmental effects from channel modifications underway and planned by the Corp of Engineers and the Soil Conservation Service. This is another activity which falls under geophysical modifications since the areas affected are large and the potential environmental effects of profound interest.

The length of watercourses channeled by these two agencies by 1972 amounted to about 11,180 miles. By 1980, if projects started and planned are accomplished, this will increase to 35,000 miles. Thus, a study of the type conducted is timely with respect to the land area to be affected in the near future.

The projects undertaken were for flood abatement, drainage of wet land, erosion control associated with channelization programs, and in rare instances related to water supply, water quality or recreation needs.

It is not possible to summarize adequately within the scope of this contract the complexity of effects associated with this type of operation. Some of the aquatic and terrestial system effects considered were: wetland drainage, cutting off of oxbows and meanders; clearing of flood plain hardwoods; water table and stream recharge; downstream effects; erosion and sedimentation; and, channel maintenance. The conclusions appear to be that while the purposes desired in initiating a channeling project are generally achieved, there are potential impacts which have far reaching implications on the ecology of the affected, surrounding and downstream areas. Some of these include

(1) Reduction in wildlife habitats and food resources through hardwood elimination

(2) Stream water quality impairment from water table lowering

(3) Increased erosion (among most severe effect) and sedimentation affecting turbidity, light penetration, algal productivity and hence fragile food webs

(4) Enhanced downstream flooding.

Clear cutting of hardwood in connection with channelization has the effect of increasing summer temperatures due to shade removal and leads to a reduction in heat sensitive organisms. Other effects are the removal of a prime habitat for swamp animals, migrating birds, and a source of leaves and other detritus upon which the productivity of the local ecosystem organisms thrive.

Lowering of the water table by drainage of a swampy area will reduce the water adsorptive capacities of the land and in turn the recharge of underground water supplies. The supply of groundwater to the channeled stream is thus reduced, especially during drought periods, with adverse effects on the local ecosystem. Reduced flow, increased temperature, and lowered oxygen levels in the stream contribute to species elimination.

Clear cutting of forests, the erosion of unstable berms or stream bottoms resulting from channeling result in erosion and sediment transfer. Inbalances in sediment and suspended solids levels contributes instabilities to an aquatic ecosystem which adversely affect productivity and species diversity. Increased turbidity reduces light penetration and hence the depth to which photosynthesis can occur. The ecosystem productivity and oxygen levels decrease along with the assimilation capacity of the stream. Settling of suspended solids onto the rocks and gravel of the stream bed destroys their roughness, buries sessile organisms and egg deposition areas--in effect reducing stream bed habitat for aquatic organisms.

Flash flooding downstream can occur if these areas do not have the capacity to contain water from the channelized areas which have a high rate of runoff. These are only a few of the many ecosystem upsets resulting from channelization of streams. Analysis of the benefits which offset these effects is complex as both direct and indirect social, environmental, and economic values and costs must be considered. When computed on a dollar basis, benefits were found to outweigh the cost of such projects by a factor of two.

Pipeline Construction

The development of superports to handle increased imports of oil and the sale by the U.S. Department of the Interior of offshore oil and gas leases are resulting in plans for the construction of major pipelines for transport of these energy resources to inland locations.

Both of these activities involve extensive dredging activities in coastal areas. A recent study by the Offshore Pipeline Committee(10) on the environmental, ecological, and cultural effects of pipeline operations in the Louisiana coastal marshes and estuaries details many of the effects of such large scale engineering efforts. The findings are sufficiently general to be applicable to developments in all marshland types.

The laying of pipelines from offshore wells in locales such as Louisiana requires traversing many miles of marshes and bays or bayous from the point at which the pipeline is brought ashore to that where conventional pipe laying can be employed. The laying of pipe up to 4 feet in diameter in such areas requires the excavation of a ditch or canal using one of several specialized techniques for wetland operation. On relatively firm ground a ditch 4 to 6 feet deep and 8 to 10 feet wide is dug by a dragline or clamshell. The spoil is usually returned to the ditch after the pipe is laid, although because of subsidence and shrinkage the volume is generally inadequate. In very wet areas, a flotation method of pipeline laying commonly used requires a canal 40 to 50 feet wide and 6 to 8 feet deep--sometimes with an additional trench in the bottom another few feet deeper wherein the pipe is laid. The spoils are piled back some distance from the canal to form a levee 3 to 5 feet high and 50 to 85 feet wide. For this type operation the total marsh area altered (canal plus levee) will range from 36-42 acres/mile.

Pipeline construction of this type is required in areas such as Louisiana where the coastal marshlands and estuaries extend 20 to 40 miles inland from the Gulf of Mexico. The value of estuaries and marshlands to the United States fisheries is reflected in the fact that two-thirds (in value) of the commercial catch and nearly all of the sport fish are composed of species which are dependent on the estuaries for some part of their lives. Shellfish, i.e., oyster, crabs, and shrimp are all dependent on the coastal estuaries. The environmental effects of construction in these areas include erosion, release of toxic substances, turbidity, salinity, and other ecosystem alterations involving plant, animal, bird, and aquatic life.

Turbidity. Coastal estuaries are frequently naturally relatively turbid. However, light penetration through the whole water depth is an important aspect of the productivity of the estuary so that prolonged unnatural turbidity levels as may be generated by operations of floatation dredge will lower or inhibit the high productivity.

Release of toxic sediments. Floatation dredge operation in areas where industrial wastes may have been released or be present in the sediments poses added problems. Certain locations within the Delaware or Mobile Bay estuaries are example areas where this problem may be encountered. Heavy metal sulfides can be dissolved from spoils by H_2SO_4 generated by the action of aerobic and anaerobic bacteria on H_2S which is prevalent in marshland ecology. Redistribution of heavy metals such as lead, mercury, arsenic, and copper have been reported to lead to eventual concentration in the tissues of oysters and bi-valve mollusks.

Barriers to nutrient flushing. Much of the aquatic animal life produced within or near the coastal estuaries depends on the spring tides "flushing" small particles of organic matter and nutrients from the marshes by alternate flooding and draining. Following fall dieback of the grasses, etc., and the abrasive action of winter winds and storms, the high spring tides serve to carry this rich food supply out into the water. The spoil banks may form barriers to this flushing activity thus reducing the food supply available to the deep water fishes.

Barriers to estuarine organisms. Just as the spring tides carry nutrients out to sea, the same tides are ridden by juveniles of many species to take advantage of the rich food supply available within the estuaries. For most species, including the commercially important shrimp species, the sea trout, Atlantic croaker, menhaden and many others, this process is obligatory in their life cycle. Barriers to this action as well as to intra-estuarine movements are frequently created by the spoil banks.

Changes in tidal flow patterns. Further stress to the balances of the estuarine environment may result from the creation of a barrier to the free exchange of water within the estuary. Areas of stagnation may occur behind or between spoil banks where one or several of the physical water quality measures may exceed ranges necessary to support life. Such changes may occur to temperature, salinity, pH, ion concentration, etc., because of the barrier effect.

Canal erosion. The presence of new navigable channels within the marsh encourages pleasure and sport boat craft to use the canals. The narrow width coupled with high speed or simply powerful engine boating leads to erosion of the banks by boat wakes. This condition varies greatly in magnitude proportional to the erodability of the spoil banks. Maximal examples, not uncommon in some Louisiana marshes, indicate widening of the 40 to 50 foot canal to 200 to 300 feet within several years. Thus, a massive, unnecessary and permanent loss of valuable marshland. The use of gas pipeline canals for boating is normaly prevented by plugging or bulk heading the completed canal. Natural water circulation patterns can also contribute significant erosion over a period to years to canals.

Marsh buggy operation. This stressor is not unique to pipeline construction operations though pipelining requires preconstruction and construction surveillance and the marsh buggy has shown to be the most effective ground transportation in this environment. Due to delicate surface balances of the marshes, one single passage by the tractor treads of the marsh buggy permanently destroys by compaction the area on which it passes. These tracts may be seen years and often decades after a single passage. Under certain conditions, erosion forces may create channels within these tracts further increasing the damage. In coastal eastern Louisiana, one marsh buggy tract eroded to a 200 foot wide by 40 foot deep channel without benefit of a hurricane storm. While an extreme case, it does indicate the magnitude which this damage can achieve.

Leaks and spills. Operation of mechanical equipment and use of chemical adhesives and petroleum products during construction of pipelines can lead to localized spills. These spills may occur within the marsh where clean-up technology is only minimally effective.

During operation, pipelines are subject to leaks whether major or minor. Because of the numerous channels within many estuaries, boat traffic with its inherent hazards to submarine pipelines may be considerable.

Control Options

The identifiable options for control of the environmental impacts from large scale engineering efforts which result in substantive modification to the earth environment include

(1) Continued research on the environmental, ecological, economic, and social impact of such operations, especially with respect to the magnitude and importance of specific effects

(2) Development of new techniques that will minimize or eliminate identified adverse effects from large scale construction and resource extraction efforts

(3) Passage of Federal legislation requiring the restoration of affected area, e.g., strip mined areas, and the use of techniques which minimize the environmental and ecological consequences.

As a consequence of the National Environmental Policy Act (NEPA) the consequences of many large scale efforts like oil and gas pipeline developments are receiving study before-the-fact. This in turn is stimulating further research on apparent adverse effects, their relative importance, and mitigation measures.

References

(1) Environmental Quality - 1972, p 26, Council on Environmental Quality (August, 1972).

(2) Battelle, "Environmental Considerations in Future Energy Growth--Volume I", Report to EPA under Contract 68-01-0470 (April, 1973).

(3) National Petroleum Council, "U.S. Energy Outlook" (December, 1972).

(4) Hill, R., "Mine Drainage Treatment - State of the Art and Research Needs", U.S. Department of the Interior, FWPCA, Mine Drainage Control Activities, Cincinnati, Ohio (1968).

(5) Reid, G. W., and Streebin, L. E., "Evaluation of Waste Waters from Petroleum and Coal Processing", EPA Ra-72-001 (December, 1972).

(6) Anonymous, "States Make Headway on Mine Drainage", Environmental Science and Technology, 3 (12), 1237-1239 (December, 1969).

(7) Charmbury, H. B., "Developments in Mine Drainage Pollution Control", Mining Congress Journal, 54 (1), 50-53 (January, 1968).

(8) Nephew, E. A., "Healing Wounds", Environment, 14 (1), 12-21 (January/February, 1972).

(9) "Report of Channel Modifications - Volume I", prepared for Arthur D. Little, Inc., for Council on Environmental Quality (March, 1973).

(10) McGinnis, J. T., et al., "Environmental Aspects of Gas Pipeline - Operations in the Louisiana Coastal Marshes", Report to Offshore Pipeline Committee by Battelle's Columbus Laboratories (December, 1972).

SECTION VI

TRACE ELEMENTS (METAL) CONTAMINANTS

Nature of Problem

Toxic trace element contaminants (principally heavy metals), as a class, have already been implicated as a particular segment of concern in the spectrum of identified environmental pollutants. Two specific substances, beryllium and mercury, have been officially declared as hazardous air pollutants and national emission standards established. Cadmium is on a proposed list. Others such as selenium, vanadium, manganese, lead, etc., are under study.

The pathways by which trace element contaminants are distributed to man are complex and encompass essentially all media and their associated ecosystems. As with many pollutants where effects are manifest at low concentration levels, control is difficult to exercise once the metals are well dispersed along a pathway. The biological conversion to even more toxic forms, e.g., organometallics, and accumulation in ecosystems further complicates the problem. Interruption of such pathways at key points through the application of control technology is a current major U.S. effort. The sheer magnitude of the pathways and sources, however, combined with a lack of information of the human health and biosphere effects of trace contaminants deficiencies and overabundance effects, underscores the future importance of this pollution problem.

Projection

Sources

Major studies have been and are being conducted by EPA and other U.S. agencies on the sources of trace element emissions to the environment. Emissions to the air have been emphasized, with quantitative estimates by industry category derived in several instances.(1,2,3,4,5) Similar quantitative estimates of emissions to the water environment do not exist, although metallic contaminants are a component of numerous industrial water discharges(6,7) and have been characterized in studies of lake and stream bottom sediments in the vicinity of industrial discharges(8). Natural sources of trace elements in the U. S. have also been studied(7) and levels in U. S. waters have been determined at selected locations(9).

Natural Sources. A 1970 survey by the U. S. Geological Survey (USGS) of trace elements in watercourses in 50 states and Puerto Rico covered As, Cd, Co, Pb, Hg, Cr(VI), and Zn.(9) Watercourses sampled were of three categories: (1) surface water for cities of generally more than 100,000 population, (2) watercourses downstream from major municipal and/or industrial complexes in each state, and (3) USGS hydrologic bench-mark stations established for measuring long-term trends in water quality. The survey showed that the elements studies are widely distributed in low concentrations, as would be expected. There was some evidence that the levels are related to man's activities in certain instances, although the amounts generally did not exceed current drinking-water standards. A recent analysis of the results of this survey data on natural occurrence of Pb, Cd, As, and Hg led one USGS spokesman to conclude that more than 90 percent of the Pb and Cd and about 67 percent of the Hg in watercourses are a consequence of man's industrial activities(7).

Industrial Sources. Industrial air and water emissions and solid waste residues contribute significant quantities of metals to the environment. The manner in which these are distributed is extremely complex. Figure 1 illustrates the variety of pathways by which a single element (lead) can impact on man, with emphasis on air emissions sources(10).

Trace element contents of wastewater from lead-zinc processing (smelters and refineries) were derived in a recent study (Table 6)(6). While the levels are low, the quantities become significant when it is realized that the 50 plant operations in the copper, zinc, and lead industry segments surveyed discharged slightly over 56.5 billion gallons of water in the 1970-71 period studied.

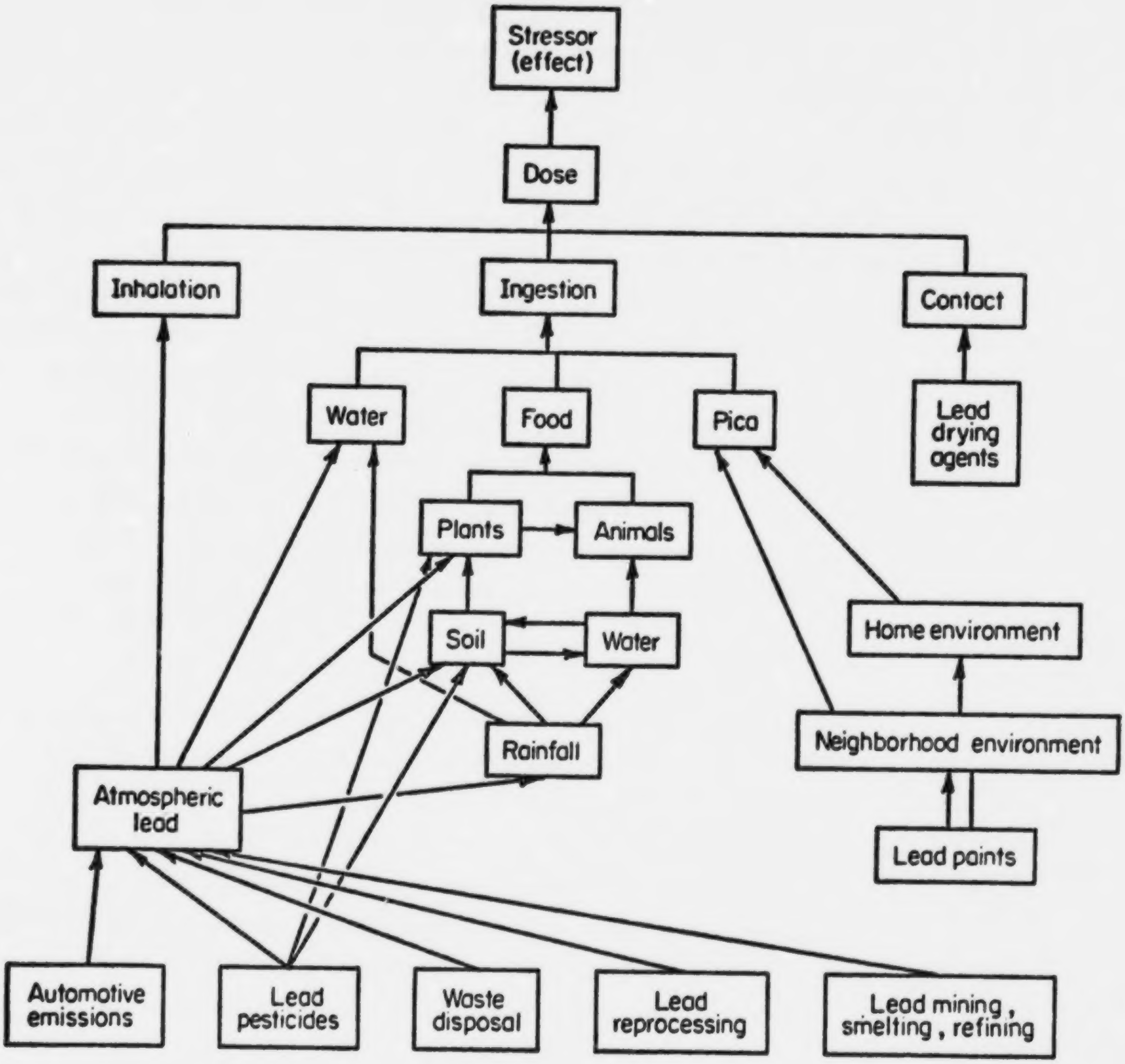

Stressor (effect)
Dose
Inhalation
Ingestion
Contact
Water
Food
Pica
Lead drying agents
Plants
Animals
Soil
Water
Home environment
Rainfall
Neighborhood environment
Atmospheric lead
Lead paints
Automotive emissions
Lead pesticides
Waste disposal
Lead reprocessing
Lead mining, smelting, refining

FIGURE 1. POLLUTION CHAIN DIAGRAM FOR THE ENVIRONMENTAL STRESSOR LEAD

TABLE 6. TRACE ELEMENT CONCENTRATIONS (mg/l) IN SMELTER-REFINERY EFFLUENTS

	Lead Smelters, Refineries					
	I[(a)]			II[(b)]		
	Upstream	Outfall	Downstream	Intake	Neutralized Acid Plant Water	Other Waste Water
As	0.11	0.15-0.46	--	--	--	--
Cd	0.002	0.02-1.09	0.03-0.113	--	7.7	0.5
Cu	0.13	0.13	0.13	--	0.06	4.0
Fe	--	--	--	5.0	7.4	1.3
Mn	--	--	--	0.9	0.7	0.5
Ni	--	--	--	--	0.2	0.06
Pb	0.03-0.03	0.07-0.157	0.03-0.05	--	0.5	11.0
Zn	0.08-0.13	0.11-2.00	0.08-0.43	--	8.0	2.0

	Zinc Smelters/Refinery[(c)]	
	Intake	Discharge
As	--	--
Cd	--	0.9
Cu	--	0.02-1.35
Fe	1.0-1.2	1.3-19.7
Mn	0.4-1.0	0.4-1.75
Pb	--	--
Zn	5.7	18-25

(a) Company surveyed effect of waste discharge on stream; outfall was combined process and cooling water. Major contributant to process water impurities was effluent from "gas conditioning" operation in which fumes and dusts were "moisturized" by spraying with water before entering electrostatic precipitator. Spray water collected in sump below conditioner and discharged.

(b) Company operates lead smelter in conjunction with sulfuric acid plant. Provided data on intake water, neutralized acid plant water prior to discharge, and "other" waste water, which includes slag granulation and cooling water.

(c) Zinc smelter in conjunction with sulfuric acid plant. Analyses show composition of water supply and combined waste discharge.

Air emissions of 15 metals (or elements such as arsenic and boron generally associated with metallurgical ores) have been estimated for a fair cross-section of commercial production-consumption sources(11). Table 7 summarizes the approximate amounts dispersed from each source. In total, nearly 264,000 tons/year are emitted. The bulk of the production-related air emissions is derived from (1) primary and secondary metals processing--lead, zinc, copper, iron and steel; (2) production of inorganics--glass, chlorine; and (3) chemical manufacture--pesticides, petroleum. Application and consumption of coal and oil, agricultural pesticides, herbicides and fungicides, and paint produced the remaining emissions.

Projections of the air emissions of various elements in Table 7 have been made and are shown in Table 8. These projections were derived using: (1) Federal Reserve Board projections of Federal production through 1985; (2) projections and information presented in U. S. Industrial Outlook - 1973; and (3) figures presented in the Annual Survey of Manufacturers 1970 and 1971. The levels shown assume no reductions in pollution due to process changes or additional levels of pollution control. Growth rates for major industry production or consumption source categories for each element were determined, e.g., iron and steel or powerplant boilers. These ranged from 2 to 10 percent, with most in the 2 to 6 percent annual range. Were it possible to apply 100 percent control, these figures would become a measure of pollution control residues available for disposal or recycle.

Sludges and solid residues (tailings) generated by industry also constitute a source of trace element contaminants, unless adequate storage or disposal is accomplished. The metal-finishing industry has been surveyed in a recent EPA study(18) with respect to sludges from some 15-to-20-thousand facilities known to exist in the U.S. Data extrapolated from questionnaires sent to members of the National Association of Metal Finishers suggest that annual sludge production ranges between 400,000 and 500,000 tons dry basis. These sludges contain potentially valuable amounts of (1) base metals -- of Cu, Ni, Cr, Zn, Cd, (2) precious metals --

TABLE 7. ELEMENTAL AIR EMISSIONS FROM U. S. PRODUCTION AND CONSUMPTION OPERATIONS--TONS/YEAR

Element	Production	Consumption	Total	Reference
Zn	118,000	33,000	151,000	(12)
Mn	16,700	2,300	19,000	(13)
V	500	17,500	18,000	(13)
Cu	12,100	1,400	13,500	(12)
Cr	4,200	7,800	12,000	(15)
Ba	7,500	3,300	10,800	(12)
B	3,900	5,600	9,500	(12)
Pb*	8,100	1,200	9,300	(16)
As	5,400	3,600	9,000	(13)
Ni	900	5,100	6,000	(14)
Cd	2,900	100	3,000	(14)
Se	300	600	900	(12)
Hg	150	650	800	(13)
Sb	250	100	350	(17)
Be	10	140	150	(13)
	180,910	82,390	263,300	

* Composited date for the 1969-1971 period.

TABLE 8. PROJECTED AIR EMISSIONS OF SELECTED ELEMENTS

	Tons of Pollutant		
Element	Base Year*	1978	1983
Zn	151,000	216,700	273,000
Mn	19,000	25,840	31,720
V	18,000	37,240	58,370
Cu	13,500	20,680	24,070
Cr	12,000	14,980	17,800
Ba	10,800	17,290	22,860
B	9,500	14,000	17,690
Pb**	9,300	11,840	14,370
As	9,000	12,750	16,990
Ni	6,000	10,940	17,500
Cd	3,000	4,090	5,050
Se	900	1,240	1,560
Hg	800	1,160	1,560
Sb	350	460	550
Be	150	200	260
Totals	263,300	389,410	503,350

* Data for 1969-71 period (see Table 7 References).

** Excludes automotive sources.

Ag, Rh, and Au and (3) other metals -- Fe, Al, Pb. Typically, concentrations ranged from a few tenths of one percent up to 5 weight percent for a single element. Disposal of such sludges in private and public landfills--the principal method used--would likely result in some leaching to the environment of toxic heavy metals.

Tailings from mineral and fossil-fuel mining constitute another major source of trace element contamination due to water leaching and airborne dusts. An estimated 1.6-billion tons of tailings per year were generated in 1970(19). And, with the continuing worldwide exponential growth of demand for raw materials the waste production could double by 1980(20).

There are other major sources of trace element contaminants to air, water and land receptors, notably automotive exhaust (Pb), leaching from municipal landfills, and more recently identified sources from incineration and land disposal of sewage sludge from municipal wastewater treatment. The concentration of heavy metals in such sewage sludges has been well documented(21). Table 9 shows a few typical values of selected elements. Finally, applications of agricultural chemicals to millions of acres in the U. S. are a significant source of Hg, Cu, Zn, Cd, Mn, and Cr.

Effects

It is beyond the scope of this report to detail all that is known about the effects of trace metals on human health and the environment at large. Sufficient information on harmful levels of metal pollutants is not yet available. It is known that levels of certain trace elements are needed in the human diet, so that deficiencies as well as excesses can be harmful. It is also known that well-publicized instances of localized disasters and serious incidents (excessive occupational exposure) have occurred wherein mercury, cadmium, beryllium, lead, etc., have been implicated because of accident, lack of foresight or lack or environmental consciousness by those having control of the polluting operation.

TABLE 9. HEAVY METAL CONCENTRATIONS IN SELECTED SLUDGE SAMPLES (ppm on dry basis)(21)

Location	Zinc	Copper	Nickel	Cadmium
Dayton, Ohio	8,390	6,020	<200	830
Monterey, California	3,400	720	220	<200
Tahoe, California	1,700	1,150	<400	40
Millcreek, Cincinnati Ohio	9,000	4,200	600	<40

Up to now, no mention has been made of the form of the trace elements noted. Different forms have widely different toxicities, e.g., Cr(VI) versus the less toxic Cr(III) and methyl mercury versus totally inorganic mercury forms. Transport along pathways in the environment is hindered or enhanced depending on the particular chemical form. Uptake by plants, accumulation in food chains, solubilization/precipitation in water and evaporation from land are also dependent on the element form.

Some known effects for a few specific elements follow(22).

Mercury. Accumulates in food webs and man. Methyl mercury is preferentially retained in organs of high-lipid content, especially the brain. In humans, mercury can affect the central nervous system, liver and kidney. In biological systems, mercury compounds are mutagenic and embryotoxic.

Lead. Despite intensive occupational, clinical and epidemiological studies, it is uncertain whether current increased exposure by man from air, food or soil sources of lead constitute a threat to health. Poisoning of children from ingestion of lead-based paints is a fact, however.

Cadmium. Itai-Itai disease in Japan from exposure to rice irrigated with river water heavily contaminated by cadmium has been documented(23). Cadmium accumulates in the renal cortex. Community and occupational exposures have resulted in chronic renal diseases. Long-term, low-level exposure effects on health are only speculative at present.

Manganese. Through a biologically essential trace element, excessive occupational exposures to manganese in the mining and metallurgical industries may be associated with increased frequency of lobar pneumonia or alterations of neuronal mediators and severe extrapyramidal disease. Disturbance in reproduction physiology is also an effect from exposure to levels much higher than usually found in the ambient environment.

Serious Consequences

There are two basic concerns with respect to trace elements and human health. One is the possibility of overexposure of population segments to relatively high levels of toxic forms due to pollution incidents such as occurred with mercury in Japan (Minamata disaster). The other is for effects due to low-level exposure over long periods; genetic, mutagenic, teratogenicity, etc. Considering the number of sources, pathways and quantities now emitted, both of these appear to be legitimate.

With respect to establishing control over the various emitting sources (i.e., inputs to area sources) the next few years may be critical.

Control Options

Control of trace element contamination of the environment will require as a minimum these actions.

(1) Increased knowledge of specific health effects, so that the standards can be set at optimum and economically reasonable levels.

(2) Establishment of safe levels in occupational environments, municipal water supplies, foods, drugs, and consumer products.

(3) Development of process, control, and monitoring technology to achieve these standards.

(4) The setting of air- and water-quality standards for the various elements related to point and area sources of environmental contamination. This implies a need for identification of sources, quantities, pollutant form, pathways, and effects for each substance.

EPA has the legislative mandate to accomplish Options (3) and (4) and is, in fact, functioning in these areas. Increased effort to insure resolution within the next decade of this widespread and complex health-environment problem is essential.

References

(1) W. E. Davis and Associates, "National Inventory of Sources and Emissions -- Cadmium, Nickel, Arsenic, Beryllium, Manganese, Mercury, Vanadium, Barium, Copper, Selenium, and Zinc" (separate document on each substance - 1968-69).

(2) Litton Systems, Inc., "Preliminary Air Pollution Survey of: Arsenic, Beryllium, Cadmium, Chromium, Manganese, Iron, Mercury, Nickel, Radioactive Substances, Selenium, Vanadium and Zinc" (separate document on each substance - 1969).

(3) Midwest Research Institute,"Particulate Pollutant System Study, Vols I, II, III" (1971).

(4) Battelle, Columbus Laboratories,"Control Techniques for Emissions Containing Chromium, Manganese, Nickel, Vanadium, Copper, Arsenic, Cadmium, Selenium, Zinc and Mercury" (1972).

(5) The Mitre Corporation, EPA Contract 68-01-0438 (under way).

(6) Battelle, Columbus Laboratories "Water Pollution Control in the Primary Non-Ferrous Industry, Vols I & II", EPA Contract 14-12-870 (July, 1972).

(7) "Cycling and Control of Metals", proceedings of a conference sponsored by EPA (Nerc-Cincinnati), NSF and Battelle's Columbus Laboratories (February, 1973).

(8) Ruch, R. R., Kennedy, E. J. and Shimp, N. F., "Distribution of Arsenic in Unconsolidated Sediments from Southern Lake Michigan", Illinois State Geophysical Survey, Geological Notes No. 37 (September, 1970).

(9) Durum, W. H., Hem, J. D. and Heidel, S. G., "Reconnaissance of Selected Minor Elements in Surface Waters of the United States, October 1970", Geological Survey Circular 643, U.S. Department of the Interior (1971).

(10) Lutz, G., et al., "Technical, Intelligence, and Project Information System for the Environmental Health Service, Vol III: Lead Model Case Study", NTIS Report Pb 194 412 (1970).

(11) Communication from A. J. Goldberg (EPA). Internal report on "A Survey of Emissions and Controls for Hazardous and Other Pollutants".

(12) Davis, W. E. and Associates, "National Inventory of Sources and Emissions: Barium, Boron, Copper, Selenium and Zinc", Sections I-V (1969).

(13) Davis, W. E. and Associates, "National Inventory of Sources and Emissions: Arsenic, Beryllium, Manganese, Mercury, and Vanadium", Sections I-V (1968-1971).

(14) Davis, W. E. and Associates, "National Inventory of Sources and Emissions: Cadmium, Nickel and Asbestos", Sections I-II (1968-1970).

(15) Battelle-Columbus, "Control Techniques for Emissions Containing Chromium, Manganese, Nickel, and Vanadium" (June 9, 1971).

(16) EPA, Office of Air Programs, "Control Techniques for Lead Emissions (no date).

(17) "Mineral Facts and Problems, 1970", U.S. Bureau of Mines (1970).

(18) Tripler, A. B., Jr., et al., "The Reclamation of Metal Values from Metal Finishing Waste Treatment Sludges", Report to EPA's Office of Research and Monitoring (1973).

(19) McVay, L. M., "Mining and Milling Waste Disposal Problems -- Where Are We Today?", Proceedings of 2nd Mineral Waste Utilization Symposium, U.S. Bureau of Mines and IIT Research Institute (March 18-19, 1970).

(20) "The Scramble for Resources", pp 56-63, Business Week (June 30, 1973).

(21) Young, D. R., et al., "Sources of Trace Metals from Highly-Urbanized Southern California to the Adjacent Marine Ecosystem", pp 21-39, Proceedings of a Conference on Cycling and Control of Metals, sponsored by EPA, NSF and Battelle (February, 1973).

(22) World Health Organization, unpublished draft criteria concepts document.

(23) Friberg, L., et al., Cadmium in the Environment. A toxicological and Epidemiological Approval", Chapter 8, Karolenska Institute, Stockholm, Sweden (April, 1971).

SECTION VII

PROLIFERATING HAZARDOUS AND TOXIC CHEMICALS

Nature of the Problem

Public attention has been focused often in recent years on newly identified hazardous chemicals or classes thereof: diethylstilbestrol, thalidomide, DDT, polychlorinated biphenyls, pesticides, phthalic acid esters. What has been startling is that, before a warning had issued, the environmental hazard had become so widespread as to seemingly preclude any immediate or short-term remedy. Today's chemicals, initially synthesized to meet the technical requirements of a new product, frequently become widely proliferated among hundreds of products of unrelated uses. Thus, PCB's showed up in paints, carbonless carbon paper, electrical transformers, coolants, etc. The manufacture, distribution, consumption, and disposal of such products introduces the associated chemicals into the environment along a variety of incredibly complex pathways, many of which impact directly or indirectly on man. E.g., in a study of street contaminants and their contribution to urban storm water discharges,(1) PCB's and seven pesticides were identified as significant components.

Of all the chemical classes now in use, pesticides appear to pose the most difficult pollution problem in the near future. Pesticides, synthesized and applied for their lethality toward pests, are spread over literally hundreds of millions of acres of the U.S. Many are resistant to biodegradation, toxic to man and accumulate in plants and animals. The effective control of this class of chemicals is fraught with social and political consequences. The discussion to follow will thus emphasize pesticides as an example of the near-term problem of proliferating hazardous chemicals in the environment.

Projections

A recent study has analyzed in detail the manufacture of pesticides in the U.S., using a broad definition of the term, viz., including rodenticides, insecticides, larvacides, miticides, mollusicides, nematocides, repellants, synergists, fumigants, fungicides, aligicides, herbicides, defoliants, dessicants, plant growth stimulators and sterilants.(2) 1971 production quantities were determined to be over 1.3 billion pounds. About 275 specific pesticides are of current commercial importance and perhaps as many as 8000 individually formulated products are marketed for end use applications. Projected 1975 quantities are only slightly higher than 1971, perhaps reflecting the current environmental concern and legislation. There is little reason to believe 1978 will be greatly different. Regardless of the slow growth in usage, the widespread use and contamination of the environment makes this a significant problem requiring near term action.

Sources

The major way in which pesticides get into the environment is through application to crops by farming. The distribution to crops by aerial dusting or spraying and direct application from the ground has created a massive area source for pesticide evaporation, runoff or transport by wind. The magnitude of this source is best visualized with respect to 1964 U.S. Department of Commerce data on crops and acreage treated as follows.

Crop	Acres	U.S. Area
Corn	63,515,000	Midwest
Cotton	13,917,000	South, Southwest
Soybeans	30,352,000	Midwest, East, Southeast
Alfalfa	28,211,000	West, Midwest, East
Tobacco	1,025,000	Southeast

Crop dusting as a method of application is a big business. In 1972 agricultural crop-dusting aviators flew about 1.6 million hours, up 11 percent from 1971, covering a record 120 million acres.(5) Justification for this method includes factors like: faster application--one airman can cover 100 acres in an hour compared to a day for a ground rig; heavy rains sometimes keep tractors out of fields; one-twentieth less fuel is used in air application; soil compaction which hurts crops is avoided. Unfortunately, this method has environmental hazards; some error with respect to placement of the chemical is likely; drift of pesticides to adjacent fields is troublesome; wildlife in the area can be affected; and the question of human effects is always present.

In addition, pesticide usage in urban areas has grown rapidly. The variety of product formulations available for application by the home owner is large. Aerosol containers for this purpose alone amounted to 100 million units in 1970.(2) Presumably, such uses contribute to the pesticide concentrations observed in street solids from eight major cities in the U.S. which were on the order of 0.00125 lb/curb mile (including PCB which was of higher concentration and the major constituent in most cases).(1) The specific pesticides identified were the more persistent ones such as the chlorinated hydrocarbons (p,p-DDD, p,p-DDT and dieldrin) and organic phosphates (methyl parathion).

Point sources of pesticides derive from the manufacture, formulation and distribution operations by industry. These emissions include

Manufacture - process water, air vents, solid waste to landfills, byproduct disposal, equipment cleaning

Formulation - handling, mixing, and packaging losses; equipment cleaning

Distribution - handling, breakage, spillage, and transportation accidents.

A recent study of hazardous wastes by EPA pinpointed pesticide residues and containers as a major problem in several of the EPA regions. Numerous examples were identified of abandoned or improperly disposed of partially filled drums, sacks, or other containers. Approximately 400 T/year of such containers were identified in the study.(3)

Major spills from highway, rail, and river transport vehicles have occurred wherein pesticides were involved. These have resulted in massive fish kills in instances and contamination of water supplies. Some 94 separate spill incidents, all involving fish kills, resulted in the 1967-1969 period (data from Coast Guard and 3 states)(4). Other data preceding that period are shown in Table 10.

TABLE 10. FISH KILLS RESULTING FROM PESTICIDES(5)

Year	Number of Reports	Total Kill Reported	Average Kill of Incidents Reporting Kill Totals
1963	60	401,415	10,849
1964	93	191,167	2,583
1965	74	770,557	12,039
1966	51	217,406	4,941
1967	43	329,130	7,654
1968	51	325,194	7,742

The distribution of these spills (Figure F-1) emphasizes the widespread nature of the pesticide problem in the United States.

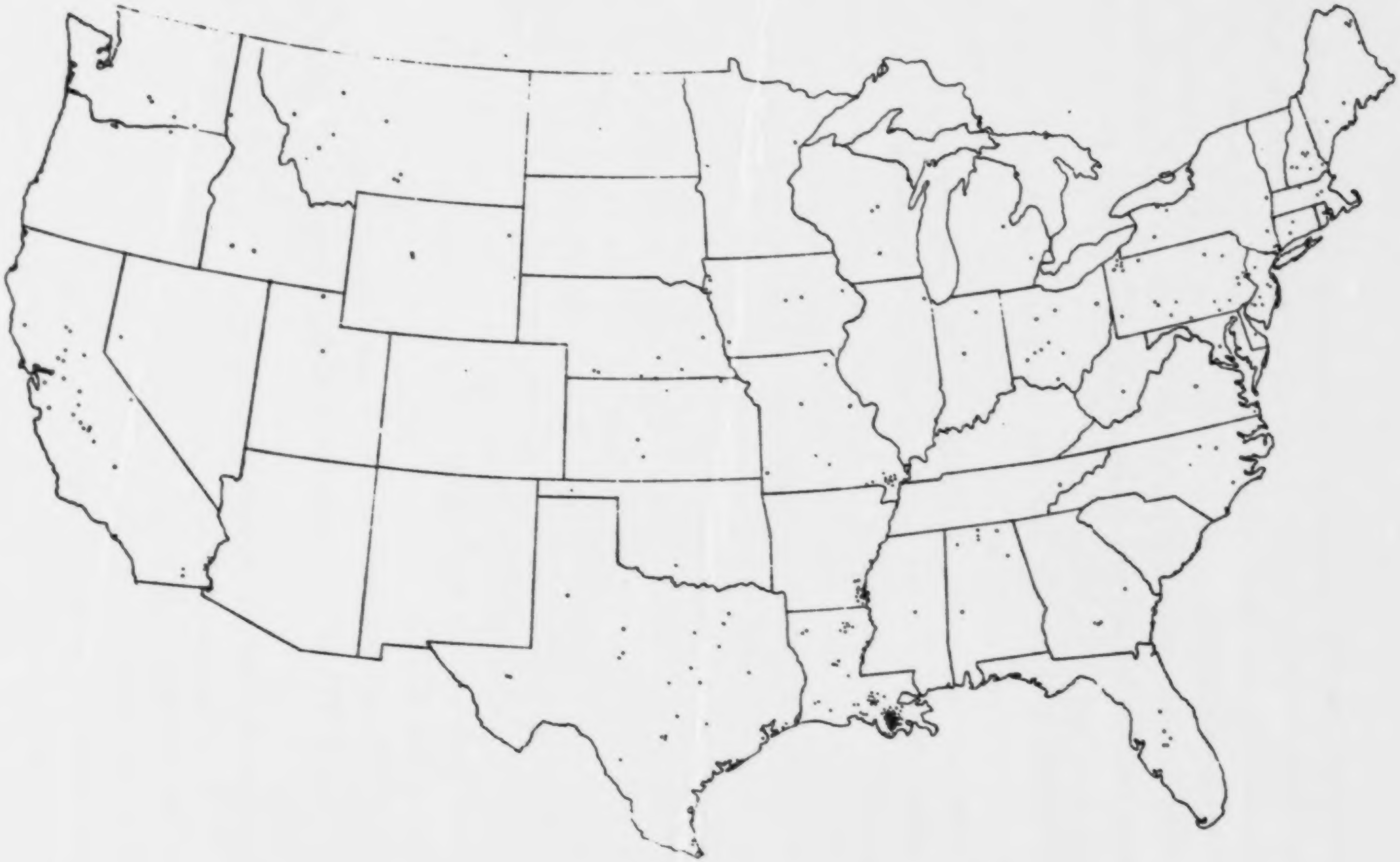


FIGURE 2. GEOGRAPHICAL DISTRIBUTION OF PESTICIDE-CAUSED FISH KILLS 1963-1968(4)

Effects

Pesticides can cause poisoning by ingestion, absorption through skin, or inhalation. A recent Labor Department estimate is that 800 deaths and 80,000 illnesses a year occur from pesticide exposure. However, the death figure has been disputed as being a factor of 4 too high with most deaths involving children under 5 years of age.(6) Of all the pesticides, the chlorinated hydrocarbon and organo-phosphorus insecticides are of major concern due to their acute toxicity.

Chlorinated hydrocarbons are very persistent and their residues in human fat tissues have been found all over the world. Organophosphates on the other hand are more readily metabolized. This persistence of chlorinated hydrocarbons was a key factor leading to the banning of DDT. Evidence exists that the general world population now carries a body burden of DDT.(7) Serious human effects of DDT such as cancer or tumors from other than direct exposure, i.e., from low levels induced in man from food, water, and air sources, are not known.

As with humans, animals also store chlorinated hydrocarbon residues in fat tissue. Accidental acute poisonings of commercial and domestic animals have occurred, usually involving the more toxic organophosphorus insecticides. Excretion of DDT in cows milk at the 3 ppm level has led to its concentration in butter to 65 ppm. Fish and birds are inherently more sensitive to pesticides than mammals. The concentration of DDT in fish and fowl via the food chain is a direct consequence of its tendency for accumulate in fat.

Some transfer and accumulation of DDT and other insecticides into plants has been noted, but this apparently does not result in a high residue level.

The widespread presence of pesticides in air, water, and land media is well known and documented, as is the fact that pesticides will volatilize into the air from soil, water, and treated surfaces.(7,8) It is this widespread occurrence and buildup in human, animal, and environmental media that makes the problem of pesticides and numerous other proliferating hazardous and toxic substances a major problem for resolution in the next decade.

Control

Passage of the Federal Insecticide, Fungicide, and Rodenticide Act (1972) has made registration of manufacturing plants and chemicals mandatory. This represents a first step toward control at the source. Likewise, the establishment of the Office of Toxic Substances within EPA and the passage of new (pending) legislation on controlling hazardous chemicals will have an impact on the problem. These actions, however, are causing the agricultural and research community to consider the use of natural pest-control agents in lieu of or in conjunction with synthetics. The consequences of this needs further study so that control, if needed, can be exercised in the early stages of use.

The pending new legislation requires testing of new chemicals being planned for production on a large scale. This raises the question of a basis for making judgments regarding what chemicals (out of the thousands entering the marketplace each year) should be tested and to what extent. The costs for thorough testing of all chemicals could be prohibitive using current animal test protocols. A methodology is needed for screening before-the-fact large classes of chemicals, and to determine priorities with respect to testing.

References

(1) Sartor, J. D., and Boyd, G. B., "Water Pollution Aspects of Street Surface Contaminants", 76-81, EPA-R2-72-081 (November, 1972).

(2) Lawless, E. W., et al., "The Pollution Potential in Pesticide Manufacturing", EPA Technical Studies Report TS-00-72-04 (available through NTIS as PB 213 782).

(3) "Program for the Management of Hazardous Wastes", Final draft report by Battelle to EPA (March 1, 1973).

(4) Dawson, G. W., et al., "Control of Spillage of Hazardous Polluting Substances".

(5) Wall Street Journal, p 22 (May 7, 1973).

(6) Chemical & Engineering News, p 2 (May 28, 1973).

(7) "Air Pollution Aspects of Pesticides", Litton Systems, Inc., NTIS Report, PB 188 091 (September, 1969).

(8) "Technical, Intelligence and Project Information System for the Environmental Health Service - Volume IV. Pesticide Model Case Study", Battelle Final Report to HEW, Contract CPS-69-005 (June 29, 1970).

SECTION VIII

EMISSIONS FROM NEW AUTOMOTIVE FUELS, ADDITIVES, AND CONTROL DEVICES

Nature of the Problem

The automobile as a major source of air pollutants is currently receiving national attention. Strict standards have been legislated on automotive exhaust emissions and these are leading to significant technological developments ranging over new engine design and modifications, development of catalytic convertors for exhaust treatment, formulation of new fuels and additives to reduce levels of legislated emission components. The adoption of certain of these technological alternatives has already occurred and others will be introduced within the next 2 to 10 years. The number of automobiles involved, their relationship to major population centers and the complexity of the impacts that result from each technological alternative suggests a need for careful evaluation before-the-fact of the consequences which are likely to occur. Some indicators of potential problems already exist.

Projection

Automobile Usage, Gasoline Consumption and Standards

The automobile has been implicated for its role in air pollution, particularly smog formation. Table 1 compiled in 1968 illustrates how transportation sources, in general, compare to other sources of air pollutants.(1) These sources are the major contributor to air pollutants in the United States.

Since 1960, new automobile purchases as a percent of registered vehicles have been at a rate of 9 to 11 percent a year (Table 12). These purchases have exceeded replacements by 2 to 4 percent per year, indicating

TABLE 11. ANNUAL PRODUCTION OF AIR POLLUTION IN MILLIONS TONS/YEAR(1)

Pollutant	Transportation	Manufacturing and Process Industry	Generation of Electricity	Space Heating	Refuse Disposal	Totals
CO	66.0	2.0	1.0	2.0	1.0	72.0
SO_x	1.0	9.0	12.0	3.0	<1.0	26.0
NO_x	6.0	2.0	3.0	1.0	<1.0	13.0
HC	12.0	4.0	<1.0	1.0	1.0	19.0
Particulate	1.0	6.0	3.0	1.0	1.0	12.0
Total	86.0	23.0	20.0	8.0	<5.0	142.0

TABLE 12. ITEMIZATION OF THE AUTOMOBILE TOTALS INCLUDING QUANTITIES REPLACED AND NET ADDITIONS FROM 1950 EXTRAPOLATED TO 2000(2,3,4,5)

Year	Total Registered Autos (Thousands)	Net Replaced		Total Purchases		Net Additions	
		Demand (Thousands)	Percent of Total	Total (Thousands)	Percent of Total	Total (Thousands)	Percent of Total
1950	40,334	2,700	7	6,500	16	3,800	9
1955	52,092	4,000	8	7,700	15	3,700	7
1960	62,258	5,000	8	7,000	11	2,000	3
1966	80,106	5,556	7	9,028	11	3,472	4
1967	82,367	6,076	7	8,337	10	2,261	3
1968	85,793	6,230	7	9,565	11	3,426	4
1969	89,156	6,219	7	9,582	11	3,363	4
1970	90,978	6,575	7	8,397	9	1,822	2
1971	92,799	8,426	9	10,247	11	1,821	2
1980	120,000	9,600	8	14,000	12	4,400	4
1990	170,000	13,600	8	19,700	12	6,100	4
2000	244,000	19,500	8	28,800	12	9,300	4

a significant growth in the numbers of autos on U.S. roads. At the present rate, by the year 2000 the number of autos will about equal the number of people in the U.S. (~250 million).

Gasoline consumption has on the average risen steadily for automobiles since cars became available, with the rate of rise being sharper since 1968. Were it not for the possibility of gasoline shortages, and hence controls to restrict usage, total gasoline consumption by cars in the U.S. would be 25 percent higher in 1980 than in 1972, based on a greater number of cars (and mileage) and increased gasoline consumption per car (Table 12).

The contribution of auto exhaust to smog in large cities has been experimentally verified and, in fact, was apparent as early as the late 1950's in the U.S. Public reaction to this problem led to the enactment of emission standards for hydrocarbons and carbon monoxide beginning in 1968 and nitrogen oxides beginning in 1972. The levels to be achieved and effective dates are shown in Table 14(6). These standards in turn have resulted in the rapid development of catalytic control devices and other approaches for use in meeting the standards.

The plan is for emission-control devices or methods to function within the limits prescribed in Table 14 up to 50,000 miles. EPA will permit replacement of catalyst at 25,000 miles in devices based on this control approach.

New Gasoline Formulations

Petroleum companies are already making nonleaded gasoline available to the public. While lead has not been banned as an additive (it has not been proven to be a major contributor to human blood level), there are definite plans to phase lead out of gasoline although Congress or EPA could change their minds on this. Rather, it is known that lead will interfere with the effective operation of the catalytic control devices being planned to meet near future standards. Removal of lead requires the reformulation of gasolines to compensate for the resulting octane rating and antiknock property reductions. These formula changes include the adjustment of both inorganic and organic constituents. There are currently some 300 fuel additives (not just for autos) in use and the expectation is that the number will increase.

TABLE 13. A LIST AND PREDICTION OF TOTAL MILEAGE, GASOLINE USAGE, AND TOTAL REGISTERED AUTOMOBILES FROM 1950 to 2000(2,4)

Year	Gallons/Mile	Gallons/Auto	Gallons (millions)	Miles/Auto	Total Miles (millions)	Total Reg. Autos (thousands)
1950	14.40	626	25,238	9,015	363,613	40,334
1955	14.53	664	33,548	9,359	487,540	52,092
1960	14.28	661	41,169	9,446	588,083	62,258'
1965	14.15	656	50,275	9,286	711,594	76,634
1966	14.10	666	53,312	9,384	751,740	80,106
1967	14.05	669	55,110	9,399	774,203	82,367
1968	13.91	682	58,524	9,488	814,030	85,793
1969	13.75	700	62,448	9,633	858,857	89,156
1970	13.66	722	65,697	9,877	898,107	90,978
1971	13.57	746	69,213	10,121	939,102	92,799
1975	13.20	758	72,700	10,000	960,000	96,000
1980	12.95	773	92,800	10,000	1,200,000	120,000
1985	12.80	782	117,000	10,000	1,500,000	150,000
1990	12.70	788	134,000	10,000	1,700,000	170,000
2000	12.63	792	193,500	9,840	2,400,000	244,000

TABLE 14. SUMMARY OF EXHAUST EMISSION STANDARDS FOR LIGHT-DUTY VEHICLES(6)

Year	gm/mile		
	HC	CO	NO_x
1968-1969(a)	3.4	34	--
1970-1971(a)	2.2	23	--
1971 (California)(a)	2.2	23	4.0
1972(2)	3.4	39	--
1972 (California)(a)	1.5	23	3.0
1973-1974(b)	3.4	39	3.0
1975(c) (Interim)	1.5	15	3.1
1975 (California)(c) (Interim)	0.9	9	2.0
1976(c) (Interim)	0.41	3.4	2.0
1977(c)	0.41	3.4	0.4

(a) 7-Mode test procedure.

(b) CVS cold-start test procedure.

(c) CVS cold-start, hot-start test procedure.

Inorganic Additives. The possible new inorganic additives, conceived as replacements for lead include manganese, nickel, phosphorus (already in use) and boron. Manganese and nickel are of interest because they contribute antiknock properties. Phosphorus--a good corrosion inhibitor--and boron result in more efficient fuel combustion. Maximum limits for these elements and lead in gasoline have been proposed as follows.(7,8)

Mn	0.1	g/gal
Pb	0.05	g/gal
B	0.01	g/gal
Ni	0.0075	g/gal
P	0.005	g/gal

Incorporation of any of these elements into gasoline at these levels would result in the maximum total quantities shown in Table 15, through 1985. The quantities shown are based on gasoline usage levels projected in Table Not all these elements would be used in one formulation.

The implications of such additions need to be explored relative to their (1) possible formation and emission of more toxic organometallics, e.g., nickel carbonyl, (2) smog production and health effects, should they be emitted with exhaust, (3) effects on operation of catalytic convertors, and (4) ultimate disposal or recycle with respect to final disposition of spent catalytic convertors. It would be foolhardy (and contrary to Clean Air Acts) to solve a HC, CO or NO_x problem by mere replacement with a technological alternative having similar or worse impact on the environment.

Organic Additives. Changes in the organic makeup of gasoline are being considered to improve octane rating in compensation for lead removal. There are three basic ways of changing the organic content of gasoline to increase octane rating: (1) increase the branch-chained alkanes content, (2) increase the content of olefins (unsaturated alkyl organic hydrocarbons), and (3) increase the aromatic content of gasoline.

The addition of aromatics is the simpler approach and of the three options is potentially the most harmful. Table 16 shows the manner

TABLE 15. RELATIVE QUANTITIES OF POTENTIAL LEAD SUBSTITUTES

Year	Gasoline Consumption 10^6 Gallons/Year	Inorganic Additives (10^6 lbs/yr) Mn	Ni	Pb	Boron	Phosphorus
1970	65,697	14.5	1.09	7.25	1.45	0.73
1975	72,700	16.0	1.20	8.00	1.60	0.80
1980	92,800	20.4	1.53	10.2	2.04	1.02
1985	117,000	25.8	1.93	12.9	2.58	1.29

TABLE 16. AROMATIC LEVELS IN GASOLINE RESULTING FROM STAGED LEAD REMOVAL(9)
(percent)

Constituent	1972	1974	1976	1980	1985
Aromatics	21.1	21.9	24.8	27.0	33.0
Olefins	15.1	14.6	13.0	11.2	8.0
Saturates	63.8	64.1	62.2	61.8	59.0

in which aromatic content would vary from current levels in gasoline if an EPA proposed schedule of lead reductions were followed.(9) The content would increase from about 22 to 33 percent between 1974 and 1985. An increased aromatic component of gasoline has been directly associated with an increase in emissions of polynuclear aromatic hydrocarbons (PNA) in exhaust. Current catalytic convertor designs (platinum and noble metal catalysts) remove between 50 to 70 percent of the PNA. The remainder would contribute to exhaust emissions. It has also been suggested that the partial oxidation of PNA by the catalysts may actually form a more toxic carcinogen than PNA itself.(8) Phenol emissions would also increase from the added aromatic components. It, too, has carcinogenic activity, especially with respect to skin and the lungs. Other reported increased emissions would be benzene, aromatic aldehydes, and nitrogen oxides.

Catalytic Convertors

The incorporation of catalysts as a means of meeting standards is planned by most American and foreign automobile manufacturers. As with most pollution-control equipment, there is a potential disposal or recycle problem and perhaps emissions associated with the devices themselves.

Catalytic convertors which function to oxidize HC and CO pollutants to harmless products (H_2O, CO_2) are of two basic groups: (1) the platinum-coated aluminate(10) and (2) the precious-metal-coated aluminate (precious metals such as rare-earth oxides of manganese and cobalt(11), copper chromite(12), and calcium aluminate)(10). The platinum or precious metals are coated on inert bases of alumina, aluminate, carborundum, and silica(10), and these bases will be either in pellet form or solid maze(13). The quantity of Pt or precious metal oxides on the packing material is approximately 0.5 and 10.0 percent, respectively.

One problem may be the future disposal or recycle of these devices. With EPA's required durability of 25,000 miles for each catalytic convertor and an assumed annual travel of 10,000 miles per automobile, the need for large-scale continuous disposal or recycle of catalytic convertors will be reflected 2-to-3 years after their installation, i.e., 1977-1980 (depending on instigation of EPA emission standards in 1975 or 1976). In Table 17, a crude estimate through 1985 has been made of the minimum quantities of spent catalyst which will require treatment. To these figures, one must add the contaminants which will be trapped with the catalysts, i.e., inorganic and organic additive residues. These residues may be such that controlled disposal will be required to prevent leaching or air emissions into the environment. Recovery of the platinum or noble metals (last two columns) may be attempted.

Preliminary work has been done on possible trace contaminant emission problems of catalytic convertors during operation of a vehicle. From this recent work, convertors have been shown to emit very fine particles. Concentrations of these metal-containing particulates (condensation nuclei) have been greater than 10^6 condensed nuclei per cubic centimeter, and the major trace metal constituents of those fine particles were basically Pt, Cu, Ni, or etc., depending on the type of catalysts or fuel blends(14). This appears to represent a contribution to air of fine particulates, which in itself is of current major concern.

TABLE 17. TOTAL QUANTITY OF CATALYTIC CONVERTORS NEEDED BY WEIGHT AND THE WEIGHT OF TRACE METALS ADSORBED

Year	Total Purchased Autos	Year Disposed	Weight of Basic Catalyst for Disposal, lbs*	Catalyst Portion (Pounds)	
				Platinum or Precious Metals	
1975	10,500,000	1980	73,400,000	367,000	7,340,000
1976	10,980,000	1981	75,900,000	379,000	7,590,000
1977	11,610,000	1982	81,300,000	406,000	8,100,000
1978	12,100,000	1983	84,600,000	423,000	8,460,000
1979	13,250,000	1984	92,600,000	463,000	9,260,000
1980	14,000,000	1985	97,800,000	489,000	9,780,000
1985	18,000,000	1990	126,000,000	630,000	12,600,000

* Assumed 7 lb catalyst per device and a single device per car.(15)

References

(1) Crocker, B. B., and Schnelle, K. B., Introduction to Air Pollution Control, AIChE Today Series, American Institute of Chemical Engineers, New York (1970).

(2) Volpe, J. A., and Bartelsmeyer, R. R., Highway Statistics 1971, 27 of Annual Series, U. S. Department of Transportation and Federal Highway Commission, Washington, D.C. (1972).

(3) American Petroleum Institute, Petroleum Facts and Figures, New York (1970.

(4) Landsberg, H. H., Fischman, L. I., and Fisher, J. L., "Resources in America's Future - Patterns of Requirement and Availabilities 1960-2000", The Johns Hopkins Press, p 132.

(5) Anon., "Population Estimates and Projections", U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of Census, Series P-25, No. 477 (March, 1972).

(6) Federal Register, 38 (126)(July 2, 1973).

(7) Rescorla, A. R., American Petroleum Institute, personal communication (July, 1973).

(8) Desmond, E. A., "Methylcyclopentadienyl Manganese Tricarbonyl - An Additive for Gasoline and Fuel Oils", personal communication (July 9, 1973).

(9) Blanchard, L. E., "Comments of Ethyl Corporation on EPA's Proposed Lead Regulations", Ethyl Corporation (May 15, 1972).

(10) Mark, H. F., McKetta, J.J., and Othmer, D. F., Kirk-Othmer Encyclopedia of Chemical Technology, Second Edition, Vol 2, John Wiley & Sons, Inc., New York (1963).

(11) Voorhoeve, R.J.H., Remeika, J. P., Freeland, P. E., and Matthais, B. T., "Rare Earth Oxides of Manganese and Cobalt Rival Platinum for the Treatment of Carbon Monoxide in Auto Exhaust", Science, 177 (4046), 353-354 (July 28, 1972).

(12) Leak, R. J., Blandenburg, J. T., and Behrens, B. D., "Use of Alumina Coated Filaments in Catalytic Matters Testing with Multicylinder Engine and Vehicles", Environmental Science and Technology, 2 (10), 790-794 (October, 1968).

(13) Division of Emission Control Tech. Mobile Source Pollution Control Program, "Automobile Emission Control the State of the Art as of December, 1972", Report to EPA (February, 1973).

(14) Balgord, W. D., "Fine Particles Produced from Automotive Emissions Control Catalysts", Science, 180, 1168-1169 (June 15, 1973).

(15) Patterson, D. J., and Henein, N. A., Emissions for Combustion Engines and Their Control, p 360, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan (June 30, 1972).

SECTION IX

DISPOSAL OF WASTE SLUDGES, LIQUIDS, AND SOLID RESIDUES

Nature of the Problem

Future problems related to the disposal of waste sludges, liquids, and solid residues are a direct result of the relatively recent passage of environmental legislation aimed at cleaning up the air, water, and land environment. Two aspects are apparent: first, with the addition of pollution control devices to air and water emission points of industrial, utility, and municipal processes, large volumes of liquid and solid residues are or will be generated. Much of the material collected has some potential value, although it may be sometime before technology for recovery of the values will become available with current institutional, economic, and political constraints. Examples of these residues current and foreseen include sulfate sludges from power plant SO_x scrubbing, sludges from increased application of secondary treatment to municipal wastewater treatment plants, inorganic dusts from add on particulate control devices required by industry and utilities (fly ash, e.g.), and ultimate residues remaining from the processing of industrial solid (frequently hazardous) wastes by contract waste disposal firms. Second, large quantities of industrial, municipal, and utility residues that were generated and routinely disposed of before the advent of environmental quality control efforts, have come under scrutiny with respect to their potential for polluting (trace metals, BOD, toxicity, etc.) various media. Past practices of dumping into watercourses, lagooning (near watercourses), burial in uncontrolled landfills, etc., can no longer be employed. Affected are sludges from drinking water treatment, dredgings, coal production residues, and slimes from metallurgical and inorganic chemical production.

Because of these and other factors, the search for suitable ultimate disposal routes has become a major preoccupation of the generators of these wastes. However, the options for such disposal have diminished.

Citizen's groups are active in campaigning against landfill sites, use of quarries (near residential areas) for sludge disposal, and acres of unsightly industrial residues. New restrictions on ocean disposal, lagoons, landfills, and landspreading, land use, and deep well injection are or will be in existence soon. Incineration is an alternative; however, emissions to the air are under tight regulation and an ash is usually generated which requires disposal too. Thus, there is a need for more research to identify and develop acceptable ultimate disposal practices.

Projections

The magnitude and effects associated with this problem are best illustrated by reference to a limited number of specific waste items within the two categories of (1) new bulk residues directly resulting from recent pollution control legislation and (2) residues from continuing past practices which present acute disposal problems as a result of new environmental concerns.

Pollution Control Residues

Sludge from SO_x Control. A large number of processes--perhaps a hundred--have been proposed for the removal of sulfur oxides from stack gases associated with combustion (primarily power plants) and industrial processes (pyrometallurgical sulfide ore processing). About ten processes have progressed to full scale demonstration programs or are in actual commercial use in the U.S. Only one, limestone scrubbing, has been operated successfully for an extended period on a coal-fired and an oil-fired power plant. The known processes fall into one of two categories--throwaway and recovery. With respect to power plants, throwaway processes, i.e., no recovery of sulfur values or recycle of the scrubbing chemicals, are likely to be applied first because of the reluctance of utilities to engage in chemical recovery type operations. Limestone scrubbing is such a process (throwaway). A recent EPA released report(1) on SO_x removal indicates that until 1980, wet scrubbing systems will predominate, especially those incorporating lime and limestone. It is estimated that $8.2 billion will be spent on such systems between 1975 and 1980 with 48 million tons/year of $CaSO_4$ sludge being generated by 1980.

Sludge and Brines from Wastewater Treatment. The almost universal adoption of secondary waste treatment by municipalities will increase the amounts of sludges generated from this source. One source estimates a 60-70 percent increase in sludge volume generated between 1972 and 1980.(2) The quantities produced per million gallons of water treated for the commonly applied activated sludge process and the emerging physical-chemical treatment schemes are shown in Table 18. On a national basis, 23 billion gallons/day of wastewater currently receives secondary treatment, resulting in an estimated 7 million tons/year (dry solids) of sludge for disposal. Thus by 1980, this amount should increase to 11 million tons/year.

TABLE 18. AVERAGE SLUDGE QUANTITIES IN MUNICIPAL WASTEWATER TREATMENT(4)

Treatment Process	Volume (gal/MG)	Dry Weight (lb/MG)
Activated Sludge*	22,500	2250
Physical-Chemical**		
Lime clarification	10,000	6500
Iron clarification	13,000	1740
Alum clarification	--	1120

* Primary + waste activated.

** Pilot plant data only.

Incineration of the sludge is one alternative. However, the tendency for heavy metals to concentrate in municipal sewage sludge raises the possibility of undesirable air emissions and/or an ash residue equivalent to around 25 lb/100 lb of dry sludge burned for controlled land disposal.(3)

Tertiary treatment and phosphorus removal in secondary treatment, when widely adopted (judged as unlikely within the next 5 years), will add even greater volumes to this waste category. Brines from the application of technologies such as reverse osmosis will require disposal by a route other than direct return to a water supply source.

Flyash. The burning of fossil fuels generates an enormous quantity of flyash for disposal. While this ash consists primarily of carbon, silica, alumina, and iron oxide, more recent concern regarding coal as a source of toxic trace elements (Hg, V, Se, Ba) may raise the question of leaching of such elements from flyash disposal areas. A crude estimate of the quantities can be based on emission factors compiled by EPA. In 1972, electric utilities consumed 336 million tons of coal.(5) At a 5-6 percent per year annual rate of growth of coal consumption in this sector, consumption in 1973 and 1978 will be about 354 and 438 million tons, respectively. Using a conservative emission factor of 130 lb flyash/ton coal (assumed 10 percent ash)(6) and 90 percent collection efficiency, the projected quantities of flyash are

1973 - 20.6 million tons/year
1978 - 25.6 million tons/year.

An incident in 1967 involving flyash aptly demonstrates the dimensions of the disposal problem. In June of that year, a dike, which contained an alkaline waste lagoon for the Appalachian Power Company steam plant in Carbo, Virginia, collapsed and released about 400 acre-feet of flyash waste in the Clinch River. An estimated 200,000 fish were killed at Norris Lake some 70 to 100 miles away and food organisms completely eliminated in a 4-mile stretch of river below Carbo resulted.(7)

Hazardous Waste Residues. In a recent study by the EPA's Office of Solid Waste Management(8) it was estimated that toxic chemical, biological, radioactive, flammable and explosive wastes are being generated at a rate of about 10 million tons annually. Most of these wastes are in a liquid form. A 5-10 percent annual growth rate is estimated as a result of increasing production-consumption, collections of toxic substances, and nuclear energy growth requirements.

Examples of the types and quantities of these hazardous wastes are(8)

Radioactive		
High Level	2×10^{5} ft^{3}	(1980 est.)
Low Level	7×10^{6} ft^{3}	(1980 est.)
Military Ordnance		
Wastes from Deactivated Munitions	7×10^{4} T	(1972)
Chemically Contaminated	2×10^{6} T	(1972)
Pesticide		
Contaminated Containers	4×10^{2} T	(1972).

Hazardous waste disposal on land is said to be increasing as a result of air and water pollution controls which cspture them from other media and transfer them to land. Denial of heretofore accepted methods of disposal such as ocean dumping also has contributed to the quantities. The processing of these wastes in private or public facilities for volume reduction, treatment to render harmless, or resource recovery will generate a fair quantity of residual solids or sludges requiring long time controlled ultimate disposal most likely on land (perhaps 20-25 weight percent of the wastes to be processed).

Other. Virtually every air, water, or solid waste stream emanating from industrial processing will generate a residue after application of control technology - not to mention nonregenerable residues associated with the technology itself (sorbent materials, flocculants, etc.). E.g., elsewhere in this report are analysis of automotive catalytic devices indicate that over 100 million pounds of spent contaminated catalyst will be generated by 1978 for either disposal or recycle.

Residues from Other Than Pollution Control Efforts

There are large volumes of residues which have historically been produced and for the most part disposed of on the land. Such disposal may be entirely appropriate as "best practice" in regions where land is available and (for sludges, muds, etc.) a net evaporative capacity exists. Unfortunately, too little attention has been paid to the selection of sites from the standpoint of runoff control, location relative to watercourses, long term possibilities for use of the land restoration of land cover, etc. Acceptable practices need to be identified and developed.

Drinking Water Treatment. Drinking water treatment plants have historically returned sludges precipitatated by alum and other coagulants, solids from water softening plants, filter backwash waters, and other residues to a nearby stream or lake.(9) The discharge of such residues has led to problems of "sludge banks" in the backwaters of slowly moving streams, stream esthetic impairments due to turbidity and color change, oxygen demand, and bacterial contamination, etc. Solids production from alum coagulation is a function of raw water turbidity as the data below for several plants show:

Plant	Turbidity	Dry Solids Produced* lb/million gal
A (New York, N.Y.)	5	84
B (Akron, Ohio)	12	143
C (Washington, D.C.)	49	455
D (Philadelphia, Pa.)	126	1100

One estimate of the annual quantities of sludge generated is 0.5 million tons/year (dry basis). This estimate applies to residues from large municipal plants treating surface water by coagulation and sedimentation, serving perhaps 60 million people with 10 billion/day of water. A figure of 300 lb of dry solids generated per million gallons treated was assumed.(10)

---

* 5 mg/l of alum coagulant used in each case.

Mineral Ore Tailings. Perhaps the largest source of waste residues are those resulting from ore and coal mining activities in the U.S. Before the advent of intensive environmental concern, it was acceptable practice to accumulate the waste residues in lagoons, abandoned quarries, and in open fields after extraction of the mineral of interest. Now the leaching from such residues into watercourses of acids, BOD-contributing organics, toxic metals, etc., and dust blown into the air have raised a serious problem related to the disposal of such large quantities of materials in the future. A few examples to illustrate the magnitude of the problem follow.

Coal. In 1969 over 435 million tons of raw bituminous coal were processed in cleaning plants, a measure designed in part to remove pyritic sulfur (up to 30 percent). This resulted in more than 100-million tons of refuse. It also is estimated that more than a billion cubic yards of coal mine wastes despoil the landscape in the anthracite region of Pennsylvania. The refuse piles are a source of acid-mine drainage and frequently spontaneously ignite and burn uncontrolled for long periods.(11)

Copper. Mill waste from the processing of copper ore is a serious problem. More than 98 percent of the ore must be disposed of after processing. Copper mill tailings account for nearly 40 percent of the total mineral waste problem, perhaps 460-million tons per year.(12)

Phosphate Rock. Phosphate ores, the primary raw material for phosphorus fertilizer is mined in Florida, North Carolina, Tennessee, Idaho, and Montana. The handling, disposal, and reclamation of phosphate slimes (colloidal clay wastes), generated in the flotation beneficiation process used, is the biggest current problem of the industry. For every acre-foot of ore matrix mined, 1.2 to 1.5 acre feet of slimes are produced. About 70-million tons per year are generated. The properties of these slimes (20-25 percent solids after years of settling) make reclaiming of the land whereon they are disposed of (basically a settling operation) difficult.(13)

Iron Ore. Iron ore tailings are second only to copper in terms of waste tonnages. An estimated 234-million tons are generated in the U.S. yearly. Most iron is now obtained from taconites. Taconite rock has an iron content of 25 to 35 percent. About 4 tons of waste are generated in forming one ton of iron ore pellets. A potentially very serious environmental problem arising from taconite tailings is being currently examined by EPA's Office of Toxic Substances. In Minnesota, such tailings are dumped at several locations into Lake Superior. Asbestos fibers apparently emanating from these residues are contaminating lake water in the dumping areas to the extent of 2.6 (10^6) fibers/liter. There is strong evidence to the effect that such fibers when ingested can cause stomach or intestinal cancer.(13,14)

Other sources of tailings include the lead-zinc, alumina (red muds), and nickel. In total an estimated 2-billion tons will be generated by 1980 from all mineral and fossil-fuel mining sources.

Dredging. Data on the magnitude of this type activity were not collected. However, one source, identified in connection with the concept of superports for large oil importing tankers, estimated 321-million cubic yards of dredge spoil would be generated in the construction of a channel 8 miles long, 90 feet deep, and 1000 feet wide(15) for a single deepwater port at Raritan Bay, New Jersey. It is known that large-scale dredging efforts are a continuing activity in the U.S.

Effects

The foregoing examples of two waste categories, pollution-control residues and industrial wastes with polluting potential, illustrate the magnitude of the problem. The major effects noted are summarized below.

Land Use - excessive land requirements at a time when land use is becoming a major issue
Esthetics - frequently nothing more than huge unsightly piles of rubbish (e.g., coal washing residues) and colored streams from acid drainage

Pollution	- air emissions (dusts, fires, etc.); water emissions (leaching of acids, toxic substances, nutrients plus spills from occasional storage lagoon breakages)
Ecology	- long-term effects from destruction of habitats, damage to aquatic and marine life through increases in turbidity, salinity and toxic substances.

It is evident that this area constitutes a major problem in the near future, especially with respect to strategies for preventing or minimizing such effects that result.

References

(1) Chemical Engineering, 56-57, July 23, 1973.

(2) Balakrishnan, S., et al., "State of the Art Review on Sludge Incineration Practice", Water Pollution Control Series #17070 DIV (April, 1970).

(3) Sewage Sludge Incineration, Report by EPA Task Force, for Office of Research and Monitoring, PB 211-323 (August 19, 1972).

(4) "Applications of New Concepts of Physical-Chemical Wastewater Treatment", Proceedings of Conference Vanderbilt University, September 18-22, 1972.

(5) "1972 U.S. Energy Use Continued Upward", New Release, U.S. Bureau of Mines (March 10, 1973).

(6) "Compilation of Air Pollutant Emission Factors (Revised)", EPA Office of Air Programs Publication No. AP-42 (February, 1972).

(7) Dawson, G. D., et al., "Control of Spillage of Hazardous Polluting Substances", FWQA Report 15090 FOZ (November, 1970), p 41.

(8) "Program for the Management of Hazardous Wastes", Final Draft Report to EPA by Battelle, March 1, 1973.

(9) Dean, J. B., "Disposal of Wastes from Filter Plants and Coagulation Basins", J. AWWA 45 (11), 1229-1237 (1953).

(10) Water Quality and Treatment, Third Edition (AWWA), McGraw-Hill (1971), p 641.

(11) "Methods and Costs of Coal Refuse Disposal and Reclamation", Bureau of Mines Information Circular No. 8576 (1973).

(12) "Vegetation Tames Mine and Smelter Wastes", Envr. Sci. & Tech., 3 (8), (1967).

(13) "Mineral Waste Utilization", Proceedings of a Symposium March 27-28, 1968, Sponsored by U.S. Bureau of Mines and IIT Research Institute (1968).

(14) Air/Water Pollution Report, 11 (31), 307 (July 30, 1973).

(15) Train, R., Statement to House Committee on Public Works, June 20, 1973.

SECTION X

CRITICAL RADIATION PROBLEMS

Nature of the Problem

Exposure of man to radiation sources which are not of a natural origin is increasing. The growth of nuclear power and electronic technology raises this issue as one which will have an impact within the 5-10 year period.

Radioactive releases from nuclear materials required for military and peaceful uses have been widely recognized as a serious problem. International nuclear test bans have been formulated to deal with the former. Releases associated with nuclear power generation, while significant, have received much study - to the extent that these sources, quantities, and effects have been projected and assessed before the fact.

Less well studied are the radiation sources associated with accelerating use of a whole spectrum of consumer, medical, industrial, military and commercial devices and systems based on electronic technology. Near term increases in the numbers of devices in use and in the power output levels suggests a need to further evaluate the problem. Thermal effects are largely known. Knowledge regarding the extent of nonthermal biological effects does not exist.

This report focuses on electromagnetic radiation in the radio-frequency range as an area within the general problem statement where information is needed to keep pace with future technology trends.

Projection

There is a constantly increasing number of electromagnetic sources in this country in the radio-frequency range. [Radio frequency (RF) will be defined very broadly as extending from the extremely-low frequencies through the microwave range or from less than 10^2 to 10^{10} Hz.] With increasing numbers of sources there is also increasing power outputs per source at many frequencies from the proposed Navy Sanguine Communication antenna at less than 100 Hz to radars at 10^{10} Hz.

The effects of RF radiation on the environment are not adequately known. Although much research has been conducted and much data compiled since the mid 1950s, there is disagreement on the effects of RF radiation on humans, animals, and other living organisms. It is agreed that above certain power levels heat is produced which can damage living organisms and below these power levels there are nonthermal effects which are less well known. There is no information, however, on what are safe levels of radiation and if the nonthermal effects are significant. This report will not attempt to discuss in detail the many aspects of the effects of RF radiation. They are treated extensively in the literature(1,2,3,4). This report will, however, attempt to summarize information available on the number of sources of RF radiation, their power levels, and their projected growth; it will also summarize the present knowledge of the biological effects on man and other animals. It will point out the presently accepted safe radiation levels and how they compare with known actual radiation levels from various sources.

RF Radiation Sources

In general RF radiation is used by man in four ways: (a) as a heating source, (b) as a detection method (radar), (c) as a communication method, and (d) as a power transmission method. The relative importance of the hazards from RF radiation sources used in these ways is probably in the order listed.

Heating Sources. Residential microwave ovens are probably the current most important potential hazard source for the general population. This is true because of the total number in use now and projected in the future. They are becoming more popular as a food heating source each year. Table 18(5) gives the number of units in use from before 1967 to the present and the projected sales for the next 4 years. Although the power

TABLE 19. RESIDENTIAL MICROWAVE OVEN INSTALLATIONS

	Retail Sales	Home Installation	Percent Saturation**
pre-1967	10,000	10,000	--
1967	5,000	15,000	--
1968	20,000	35,000	--
1969	30,000	65,000	--
1970	50,000	115,000	0.2%
1971	120,000	235,000	0.4%
1972	250,000	485,000	0.7%
1973	375,000*	860,000	1.3%
1974	560,000*	1,420,000	2.2%
1975	840,000*	2,260,000	3.5%
1976	1,250,000*	3,510,000	5.4%
1977	1,750,000*	5,260,000	8.1%

* We consider these estimates to be conservative.

** It is important to note that the consumer microwave oven is not sold as a replacement for a conventional range, and is, therefore, not limited by replacement rates, nor by new home starts.

level of residential microwave ovens is in general 600-800 W, much lower than industrial heating units, there is a potential for 1.5 to 2 million people being affecting by the present nearly 1/2 million installations. This is projected to increase more than 10 to 1 in the next five years. Although the power level is lower than industrial heating sources and the ovens can be made completely safe with proper shielding and door interlocks, it is estimated that perhaps 20,000 to 100,000 people could presently be affected given only a few percent of defective units. This is in constrast to the few thousand people that operate and come in contact with industrial heating units. Leakage levels of up to 75 mW/cm^2 have been measured at 5 cm from defective ovens with the door closed. With the door open the level would be 200-700 mW/cm^2 at a distance of about 30 cm.

The commercial microwave oven market is estimated to have about 125,000 units now in use.(5) The sales for 1971 were estimated at 18,000 units and are growing at perhaps a 10 percent rate per year, meaning about 250,000 units in use by 1978. The power level of these units is somewhat higher than residential ovens, about 1 to 2 kW. However with proper manufacture they should be as safe as the residential units.

Industrial microwave heating units have not had the growth predicted in the early 1960s. This is primarily because initial cost has been prohibitive. There are estimates that the industrial microwave units in present use are less than 300 units with a potential risk of exposing 3,000 persons.(6) It is predicted that their use in industry will grow slowly, probably only a few percent per year. In contrast to microwave ovens, industrial heating units, have a much higher power output - about 1 kW to more than 100 kW. They cover the frequency range from 10^7 to 2.45 (10^9) Hz and are more difficult to shield than ovens because many are fed by conveyor belts. Therefore, although they do not affect as many people as residential ovens, because they have much higher power levels and are more difficult to shield, consideration should be given to safety regulations for these radiation sources. Leakages of up to 200 mW/cm^2 have been measured from these sources.(6) However, they can be made safe with proper design.

Medical diathermy equipment is another source of RF radiation used for heating. Diathermy equipment operates in the UHF frequency range (300 to 3000 MHz) and at power levels of 10s of watts. Diathermy equipment is potentially hazardous if improperly used. Cases are on record in which eyes were presumably damaged while irradiating the sinuses. The number of units in use is not known but sales of 5.4 million have been reported for 1972 and 8.0 million predicted for 1976. Assuming a figure of $10,000 per unit, over 500 would have been sold in 1972 with 700-800 estimated for 1976. Therefore, there must be 10s of thousands in use at present.

Detection Sources. The major source of RF radiation from equipment used primarily for detection is radars. Other sources of far less power level and probably of little environmental significance are inspection methods, moisture meters, and industrial monitoring devices. High powered radars are used both by the military and commercial airports and aircraft. There is a definite hazard from high powered radars within a distance that is dependent upon the output power, the gain of the antenna and the wavelength of the radiation. The power output of military radars vary from that of about 300 kW average for the largest search radars such as BMEWS and TRADEX to a few watts average for tracking radars with short pulses. The distance from the radar to a point in the center of the main beam of the radar where the power density is below the standard safe level of 10 mW/cm^2* is calculated to be 11,000 feet for Tradex and 7,600 feet for BMEWS. For the AN/FPS 16, a missile tracking radar, this distance is about 1,300 feet. A 1969 report(7) from the Pacific Missile Range at Point Mugu, California, states that the AN/FPS 16 complex creates a hazard on the ground or on the optical trackers platform only when the depression angle of the antenna dish is greater than -3.5°. However, under normal operating conditions the radar is never depressed below -1.7° and personnel on the ground would not be in the center of the main beam. There are also high-powered military radars in the HF frequency range which have been measured to be safe beyond their enclosing fence.

---

* See subsequent section for discussion of establishment of standard safe level.

The number of radars in use, either military or commercial is not known. Military data are always difficult to obtain and it is difficult to distinguish between operating and proposed units. However, there appear to be a decline in the sales of radar for this purpose. Estimates have been made of $1 billion in radar sales in 1973 and $0.9 billion in sales for 1977. This is probably caused by the reduction in defense spending.

Communication Sources. Radiation levels found in the vicinity of high-powered broadcasting stations in most practical instances are considerably lower than those usually associated with biologically hazardous fields. However, very close to high-powered broadcasting antennas it is possible to attain field strengths approaching the safe minimium.

The growth of radio broadcast stations appears to be nearly linear. Table 20 shows the number of TV and radio broadcast stations in the U.S.(8)

TABLE 20. TOTAL BROADCAST STATIONS IN U.S.

Year	TV	Radio
1945	6	930
1950	97	2832
1958	421	3310
1960	562	4256
1965	674	5537
1971	892	6976

AM stations range in power from the Voice of America station of 500 kW to some stations of only watts. Standard AM broadcast stations are limited to 50 kW. 131 AM stations in the U.S. operate with 50 kW power. FM stations have effective radiated powers (antenna gain times transmitter power) of up to 100 kW. 209 FM stations operate with 100 kW of power. TV stations operate at up to 5 MW.

A calculation of the field strength of a 50 kW AM station at 550 kHz using a simple monopole gives a field strength of about 10 V/m at 160 meters and about 0.1 V/m at 160 km. (200 V/m is the safe exposure level that is comparable to the 10 mW/cm^2 value given for microwaves.) These values could be doubled if an antenna with a gain of 4 was used. The field strength for FM and TV stations is higher than that from AM radio stations. A field strength of about 75 V/m is attainable at 5 MW effective radiated power at 160 meters. This value would be for a worst case in the main beam of the antenna.

Other communication sources, such as used for support to industry and transportation, have lower power and add to that of commercial broadcasting. A recent survey(9) discloses that the number of such sources is nearly proportional to the population density. New York has a total of 2,129 communication devices--346 military, 477 other government, and 1306 non-government.

Microwave relay equipment represents another source of communication radiation. These repeater systems are used for data transmission and other communications. The total number of these stations is not known but the predicted volume of sales for 1973 is $195 million. The projected sales for 1976 is $210 million. Apparently this area is not growing fast.

It is clear from the above data that the number of communication transmitters will probably increase linearly for the next five years. However, it is probable that the power level per device will not increase as commercial broadcast stations are power limited and they are the highest-powered sources.

Power Transmission Sources. One possible use of microwave radiation that may provide a pollution-free source in the future is that of transmission of energy from space. If a solar cell array were placed in synchronous orbit, the collected energy could be transmitted to the earth via microwaves. Calculations have been made for such a system on the basis of a 10^{10} watt source. For a frequency of $.3(10^9)$ Hz this would require an orbiting solar cell array of about 5 miles square, a transmitting antenna in space (23,000 miles from the earth) about 1 mile square, and receiving antenna on earth about 6 miles square. The power density at the ground above this antenna would be only 25 mW/cm^2 which may be essentially biologically harmless. It would probably be fenced in to prevent exposure to humans as this level is above the recommended safe level of 10 mW/cm^2. This method of transmitting power received from the sun in space holds great promise for a pollution free power source and is technically feasible although the cost would be high. However, if it is eventually constructed radiation hazards must be carefully evaluated.

Radiation Level Survey in Washington, D. C.

The results of a recently published survey of RF radiation in the Washington, D. C., area are of particular importance to this report. During the summer of 1969, the U.S. Public Health Service and White Electromagnetic Inc., monitored radiation from 20 Hz to 10 GHz at 10 selected sites within a 25 mile radius of Washington. The location was chosen with preference given to high density population areas near high-powered electromagnetic sources. A listing was obtained from the Electromagnetic Compatibility Analysis Center of Annapolis, Maryland, of all emitters with an average output above 10 W reported to be located within a 50 mile radius of the center of Washington. There are 1430 communication sources and 99 radar sites. Power outputs ranged from 0.1 kW tc a 5 MW radar installation. More than 200 listings had power outputs of 10 kW and above. It should be emphasized that these data include only unclassified sources. Tables 21, 22, and 23 summarize the data given in the report. Table 21 is the maximum power density level observed in four biologically relevant frequency bands. Table 22 is the power density in the broadcast bands for site 1 which was highest in these bands. Table 23 is the total power density over the entire frequency band measured at the ten sites. These peak levels represent a worst possible case. True average values of power densities would fall below these peak values to a degree depending upon the source and its modulation characteristics.

TABLE 21. MAXIMUM OBSERVED POWER DENSITY LEVELS IN FOUR BIOLOGICALLY RELEVANT FREQUENCY BANDS

Frequency (MHz)	Site	Power Density exposure (mW/cm^2)
Less than 400	Holy Cross Hospital	3.9×10^{-4}
400- 1,000	Montgomery Mall	1.1×10^{-5}
1,000- 3,000	National Airport	7.7×10^{-3}
3,000-10,000	National Airport	1.4×10^{-4}

TABLE 22. TOTAL POWER DENSITIES OVER RADIO AND TELEVISION BANDS (FOR SITE NUMBER 1, HOLY CROSS HOSPITAL)

Band	Frequency (MHz)	Total Power Density (mW/cm^2)
Radio - AM	535 KHz - 1.605 MHz	3.5×10^{-4}
Radio - FM	88 MHz - 108 MHz	4.3×10^{-5}
TV - VHF	54 MHz - 73 MHz and 75.4 MHz - 88 MHz and 174 MHz - 216 MHz	3.9×10^{-7}
TV - UHF	40 MHz - 890 MHz	3.9×10^{-9}

TABLE 23. TOTAL POWER DENSITIES OVER ENTIRE FREQUENCY RANGE FOR EACH OF 10 SITES

Site	Total Power Density (mW/cm^2)
1. Holy Cross Hospital	3.9×10^{-4}
2. Montgomery Mall Shopping Center	2.2×10^{-4}
3. Cameron Station	3.2×10^{-5}
4. Andrews Air Force Base	2.2×10^{-5}
5. Washington Mall	2.6×10^{-5}
6. Brentwood Park	8.6×10^{-5}
7. Sibley Memorial Hospital	7.0×10^{-6}
8. Duval Senior High School	7.5×10^{-7}
9. National Airport	7.9×10^{-3}
10. Darnestown, Maryland	2.5×10^{-4}

The conclusion from this survey is that the peak ambient radiation originating from manmade RF sources at the 10 sites monitored approach a maximum of 10^{-2} mW/cm^2. This is stated to be accurate within + 10 dB. If high powered pulsed radar signals are excluded from the totals, the maximum was stated to be more nearly 10^{-3} mW/cm^2. The average would fall even lower. The average background therefore is at least 2 to 3 orders of magnitude lower than any published U.S. recommendation for exposure to RF radiation.

Effects of RF Radiation on Man

Thermal. It is difficult to summarize briefly the vast amount of research on the biological effects of RF radiation on man and animals. The early work was generally confined to the effects produced by heat in the tissue. The history of concern for the effects of high-frequency microwave or radar energy on the human body goes back even before the early days of radar. Apparently, long-wave diathermy was being used as early as 1900. By 1935, frequencies of 10 MHz were being used for diathermy. Between 1935 and 1950, there were tales of the sterilization and other serious effects of radar, but nothing concrete was established. The heating effect of radar energy was known. Technicians stood in the beam of radar to warm themselves in cold weather. The hand was held in front of waveguide outputs to see whether the radar was operating.

Experiments with animals in the late 1940s established the fact that microwave energy could be hazardous. In 1952, it was established that exposure to energy levels of 100 mW/cm^2 for an extended period could cause damage to the eyes. According to the best evidence available,(1) the most important effect of microwave absorption is the conversion of the absorbed energy into heat. Exposure of various species of animals to wholebody microwave radiation at levels of 100 mW/cm^2 or more is characterized by a temperature rise which is a function of the thermal regulatory processes and active adaptation of the animal. The end result is either reversible or irreversible change depending on the conditions of the irradiation and the physiological state of the animal. Schwann, et al., has done extensive research on the heating effects of RF radiation on the human body. His main conclusions on the effects of various frequencies and the depths of energy penetration can be summarized as follows:

(1) In a three-layer model of the human body at low frequencies well below 1000 MHz and at high frequencies well above 3000 MHz, simple conditions exist. The percentage of incident energy absorbed is nearly independent of skin

(2) In the range from 1000 to 3000 MHz, the skin and fat layers contribute to the impedance, and the power absorption may vary from 20 to 100 percent. At some frequencies in this range, the fat layer may be one-quarter wavelength in thickness and perform an impedance-matching function.

(3) Heat development occurs predominantly in the deep tissues below about 900 MHz and at the body surface above 3000 MHz. In between is a transition range where more difficult relationships apply.

To summarize the threshold levels for which irreversible damage is done to several organisms by heating, Mumford(3) presents the data of Figure 3. These data show that the harmful power density is determine both by amplitude and time of exposure. All authorities would not agree, but these data probably represent a reasonable average.

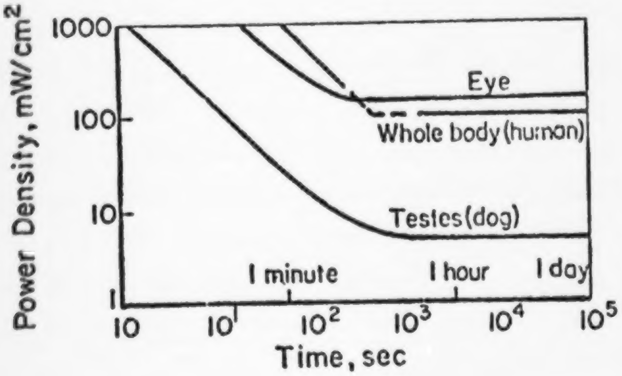


FIGURE 3. THRESHOLD LEVELS VERSUS TIME FOR THREE SENSITIVE STRUCTURES

Nonthermal. Much controversy has arisen concerning the relative importance of thermal versus nonthermal effects of microwave radiation. Thermal effects have been well demonstrated and documented, but the evidence for a nonthermal effect is at best only suggestive.(1) The evidence presented has generally been in one of several areas: microscopic, biochemical, cataract production, and neurological. Pearl-chain formation with blood cells and bacteria is considered to be biologically insignificant.

The possibility that microwaves may interact with the central nervous system (CNS) without significant heating has been suggested by several Soviet investigators(4). Although some Soviet investigators describe the thermal nature of microwaves, the majority stress nonthermal or specific microwave effects at the molecular and cellular level, in contrast to studies performed in the United States that generally reflect the physiological response of the organism to the thermal burden imposed by microwaves.

A considerable body of literature has grown in the USSR on transient functional changes following low-dose 10-mW/cm^2 microwave irradiation studied by conditional response experimentation. The Soviets have strongly and repeatedly stressed that the CNS must be considered as being moderately or highly sensitive to radiation injuries. Their conceptual basis for this view is largely centered about Pavlovian "nervism". Very briefly, this theory may be interpreted to mean that the CNS exerts a controlling influence over all types of reactions in the organism, including various local tissue reactions. Nonnervous reactions are considered as only of secondary importance because of the basic controlling role of the central nervous system in the whole organism. Thus in considering microwave pathogenesis, Soviet physiologists have persistently sought the CNS mechanism that might be responsible for each microwave-induced phenomenon. Their work in this area has been criticized because of limited statistical analysis of data, inadequate controls, and lack of quantification of the results. Conditional-response studies intrinsically do not lend themselves to objective interpretation.

There has alos been considerable investigation in the U.S. into nonthermal effects and in recent years it is generally agreed that these effects exist but it is not fully known how important they are.

An important area of nonthermal concern is the research done in the U.S. on project Sanguine. The question of whether large currents flowing at extremely low frequencies (ELF) would have effects on life has been extensively researched for project Sanguine.(12) Project Sanguine is a Navy program on development of a device for communicating radio signals at ELF (in the neighborhood of 60 Hz) to submarines. The currents on some of the proposed antenna systems would be an order of magnitude than those existing on high-voltage, electric power transmission lines.

Under the Sanguine program a series of laboratory studies of animal behavior, animal physiology, animal fertility, cytogenetics, insect mutagenics, and plant germination and early growth were performed at field intensities several times that of the proposed Sanguine system. No substantive evidence was found to indicate that electromagnetic energy at the frequencies and field intensities associated with the Sanguine concept will produce biologically significant reactions. Also, there is no reason to predict that there will be any regularly occurring currents of higher strength than the proposed Sanguine system for many years.

If a low level ELF mechanism were to exist, it would have to be different from the microwave mechanism since biological material readily absorbs short-wave energy and is generally transparent to long-wave energy. To date, no such mechanisms have been described.

Radiation Standards

Because of the known harmful effects of microwave radiation, various organizations began to establish safe levels for observance by personnel in the vicinity of antennas. Mumford(3) gives a history of the development of safe levels, which eventually resulted in the establishment in 1957 by the Bell Telephone Laboratories and Rome Air Development Center of 10 mW/cm^2 as the safe level over the entire microwave spectrum. In 1958, at the Second Tri-Service Conference on the Biological Effects of Microwaves, it was reported that the Navy, the Army, and the General Electric Company were considering 10 mW/cm^2 as the upper limit for safe exposure.

Michaelson(2) summarizes present safety standards for microwave radiation in the U.S. Safety from this hazard is assumed by the proper observance of the American National Standards Institute (ANSI) C95.1 Standard (1966) which specifies a maximum exposure level of 10 mW/cm^2 under normal environmental conditions averaged over any possible 0.1 hour. This has been and continues to be the generally accepted safety standard in the Western world for individuals in microwave radiation fields.

The ANSI C95.1 standard of 10 mW/cm^2 is roughly a factor of ten below thresholds of damage by thermal effects, assuming a long duration of exposure--i.e., one quarter hour or more. The 10 mW/cm^2 level is based on thermal equilibrium conditions for whole-body radiation. Temperature rise is determined primarily by the body's ability to dissipate heat; factors affecting this would be significant in terms of the consequences of whole-body irradiation. Heat dissipation capabilities are better for partial-body radiation; higher levels of irradiation would therefore be acceptable. This is the case in medial diathermy, where the levels may be at 100 mW/cm^2 or higher.

While the limit of 10 mW/cm^2 served as a practical exposure level in the military in the U.S. for several years, it was felt that the duration of exposure was important, and that higher levels could be tolerated for shorter periods. Applying toxicological criteria (i.e., the duration of exposure to a toxic agent multiplied by concentration of that agent during exposure represents the hazard), new guidelines were developed and published as an Army-Air Force Manual in 1965 (AFM 161-7, 1965). In this document exposures of personnel within limited occupancy areas is permitted only for the length of time given by the following equation:

$$Tp = \frac{6000}{w^2}$$

where Tp = permissible time of exposure in minutes during any 1-hour period.

w = power density in area to be occupied in mW/cm^2.

The equation is useful only for power densities up to 100 mW/cm^2, and because exposures of less than 2 minutes are operationally impractical, its use for power densities above 55 mW/cm^2 was not recommended.

The Soviets have a much lower standard level of exposure. They specify an allowable limit of 1 mW/cm^2 for up to 15 minutes, a limit of 0.1 mW/cm^2 for up to 2 hours, at a limit of 0.01 mW/cm^2 for full days exposure. These limits are not believed necessary by the majority of U.S. authorities.

Consequences of RF Radiation Environment

It is evident from the present knowledge of the RF radiation environment that there are specific hazards that present current dangers and must be controlled with safety devices and adequate education of source operators. However, there appears to be no eminent danger that the eminent RF radiation level in any part of the country will become so large that the general public is in danger within the next five years. The greatest hazard, from the standpoint of the total number of people exposed is the residential microwave oven. There are strict, adequate, manufacturing standards for this device in effect. Unfortunately, there is no method to warn the average housewife of the danger or to show her how to discover if leakage occurs. High powered radar and industrial microwave heat sources present real hazards to a small number of persons. They can readily be protected by such means as absorbing loads at exits, in the case of heating units, or protective fences and shielding in the case of radar. Commercial broadcast stations are no significant hazard now or in the next five years. To prevent the proliferation of RF radiation from increasing in power and number without proper foresight and preparation, there is need for further research in several areas. The motto of the Sierra Club appears to be appropriate to this area: "not blind opposition to progress but opposition to blind progress".

The areas suggested for further research and regulation are:

(1) Further investigation into nonthermal effects is needed, both those produced by low power levels and nonthermal effects produced by high power levels that also produce heating.

(2) There are needed safety regulations for industrial heating sources. No regulation comparable to those for residential microwave ovens are in effect.

(3) There is a definite need for an RF total-energy integration indicator analogous to the X-ray film badge. Only power density levels can presently be measured but the total time-power product cannot at present be evaluated.

References

(1) Michaelson, S. M., "Human Exposure to Nonionizing Radiant Energy-Potential Hazards and Safety Standards", Proceedings of IEEE, 60 (4), 389-421 (1972).

(2) Michaelson, S. M., "Biological Effects of Microwave Exposure--An Overview", Journal of Microwave Power, 6 (3), 259-267 (1971).

(3) Mumford, W. W., "Some Technical Aspects of Microwave Radiation Hazards", Proceedings of IEEE, 49 (2), 427-447 (1961).

(4) Influence of Microwave Radiation on the Organism of Man and Animals, I. R. Petrov, Editor, translated from Russian, NASA Technical Translation NASA TT F-708, February, 1972.

(5) McConnel, D. R., "The Impact of Microwaves on the Future of the Food Industry: Domestic and Commercial Microwave Ovens", Journal of Microwave Power, 8 (2), 125-127 (1973).

(6) Eure, J. A., et al., "Radiation Exposure for Industrial Microwave Applications", American Journal of Public Health, 62 (12), 1573-1577 (1972).

(7) Tapie, R. L., "A Study of Personnel Radiation Hazards Created by Selected High Powered Radar Sets", Pacific Missile Range, PMR-TM-69-6, October 23, 1969 (Unclassified).

(8) Tell, R. A., "Broadcast Radiation: How Safe is Safe?", IEEE Spectrum, 9 (8), 43-51 (1972).

(9) Lynn, J. F., "Man-Made Electromagnetic Noise in Southern California and Southern Nevada", IEEE Transaction on Electromagnetic Compatibility, 14 (3), 92-96 (1972).

(10) Smith, S. W., and Brown, D. G., "Nonionizing Radiation Levels in the Washington, D. C. Area", IEEE Transaction on Electromagnetic Compatibility, 15 (1), 2-6 (1973).

(11) Schwan, H. P., and Li, K., "Hazards Due to Total Body Irradation by Radar (U)", Proc. IRE, 44 (11), 1572-1581 (1956).

(12) "Sanguine System Find Environmental Impact Statement for Validation and Full Development, Technical Annexes, Data for Assessing the Environmental Input of Sanguine", PB 199-732-F-2, Electronic Systems Command, Department of the Navy (April, 1972).

SECTION XI

FINE PARTICULATES

Nature of the Problem

Chemically active and inert fine particulates emitted to the air constitute a potentially serious health hazard due to their retentivity in the human respiratory tract. This problem ranks high in terms of (a) direct health effects on man, (b) multiplicity of sources, (c) the relative persistence and pervasiveness of fine particulates once they are emitted, and (d) the difficulty of control before, and mitigation after, emission. Even with the best available control technology, which will result in a significant reduction in total particulate emissions, a major fine particle fraction will be emitted. The health hazard can be quite out of proportion to the mass involved, whether the particulates are chemically active or inert.

Projection

Fine particulate matter is defined for the purpose of this study as a material that exists as solid or liquid in the size range of 0.01 to 2 microns in diameter.(1) The lower size limit of 0.01 micron is based upon considerations of potential adverse effects of particulates on human health. The upper limit is based upon the fact that the collection efficiency of present control equipment deteriorates significantly below 2 micron particle size.

Environmental Effects

A comprehensive review and assessment of various environmental effects have been documented in an EPA report entitled "Air Quality Criteria for Particulate Matter".(2) The environmental effects described include: (1) effects on health, (2) effects on visibility, (3) effects on climate near the ground, (4) effects on vegetation, (5) effects on materials, (6) effects on public concern, (7) suspended particulates as a source of odor, and (8) economic effects. The first two are probably among the most serious effects and have been chosen for emphasis here to illustrate the environmental effects of fine particulates.

Effects on Health. Certain particulate pollutants are intrinsically toxic due to their inherent chemical and/or physical properties. Substances in this category include: mercury, beryllium, asbestos, lead, and cadmium. The health hazards posed by these substances have been reported in a series of documents prepared for EPA by the National Academy of Sciences and other documents, citing evidences obtained from toxicological and epidemiological studies.

The health effects of mercury, beryllium, and asbestos are documented in a report(3) released by EPA as a background for establishing national emission standards. Airborne mercury may be inhaled and absorbed into the blood. Chronic exposure to mercury affects the central nervous system, producing tremor and psychological disturbances. Other symptoms include loss of appetite, loss of weight, and insomnia.

Two forms of lung disease have been known to have resulted from exposure to beryllium. An acute pneumonitis has been observed in workers who were occupationally exposed to beryllium. Berylliosis, which is the chronic form, has been observed in individuals who have never been occupationally exposed to beryllium.

Some 40 percent of workers heavily exposed to asbestos eventually die of diseases related to the exposure.(4) The lungs of such individuals develop fine scars, a condition commonly called asbestosis. In addition, about 7 percent of workers directly exposed to asbestos develop a rare, lethal form of cancer called mesothelioma on the surface of the lungs or abdominal cavity. A still larger number (about 20 percent) develop carcinoma of the lung.

Clinical lead poisoning produces severe abdominal cramps, headaches, constipation, loss of appetite, fatigue, anemia, motor-nerve paralysis, and encephalopathy.(5) Information is lacking regarding long-term on chronic effects of lead at environmental levels of exposure, especially at levels that do not produce apparent clinical lead poisoning.

Exposure to cadmium oxide fumes and dust has been known to produce emphysema, bronchitis, and general lung damage.(6) Chronic exposure results in kidney damage, anemia, and liver disfunction. Cadmium intake poses a particularly serious hazard because it accumulates in the body.

Other substances considered to be potentially hazardous particulate air pollutants include: nickel, vanadium, manganese, chromium, zinc, copper, arsenic, and polycyclic organic matter (POM).(6) Documents concerning these substances are being prepared for EPA by the National Academy of Sciences. The POM, of which benzo(a)pyrene is the prime example, has attracted considerable concern due to its known effect on laboratory animals as a carcinogen.

A wide variety of supposedly "inert" particulate materials are pulmonary irritants which produce alterations in the mechanical behavior of the lungs, the alteration being predominantly an increase in flow resistance.(2) The irritant potency is particularly severe with particles below 1 micron size and high particle concentration.

Particulate pollutants also may act as a carrier of an adsorbed toxic substance, which can produce a synergistic effect whereby the effect of the adsorbed material is magnified.(2) The prime example of this effect is the interaction of particulate pollutants and sulfur oxides. Preliminary results from EPA's Community Health and Environmental Surveillance System (CHESS) study have indicated that a potential correlation exists in air between sulfur oxides and fine sulfate particles, and adverse health effects. It is possible to speculate that a similar correlation exists between nitrogen oxides and fine nitrate particles.

Effects on Visibility. Fine particles suspended in the air can cause reduction in the visibility. The effect is primarily due to the scattering of light by particles in a relatively narrow size range between 0.1 and 1 micron. Reduced visibility can have serious implication for aircraft operation. The visibility is inversely proportional to particle concentration.(2) The visibility in a rural area with a typical particle concentration of 30 micrograms/m^3 is 25 miles. For common urban concentrations of 100 and 200 micrograms/m^3, the visibility is reduced to 7.5 and 3.75 miles, respectively.

Sources of Selected Air Pollutants

Quantities of emissions by sources of selected hazardous materials are listed in Tables 24 through 29. The hazardous pollutants include mercury, beryllium, asbestos, lead, cadmium, and POM. The emission data are probably based on 1968-1970 period. The emission quantity refers to the total emission. A significant portion of the total emission probably exists in the form of fine particulates.

The important sources of mercury are consumption of paint, incinerators, and power plant boilers. These three sources contribute 66 percent of the total nationwide mercury emission.

The major source of beryllium emission is power plant boilers, which contribute 70 percent of the total nationwide emission.

The great majority of asbestos emission orginates from mining operations which contribute 82 percent of the total nationwide asbestos emission. Important urban sources include asbestos products manufacturing and the wear of automobile brake linings.

The great majority of lead emission is from gasoline combustion, which contributes 95 percent of the total nationwide lead emission. The lead emission will be substantially reduced when the use of lead alkyl compounds as a gasoline additive is discontinued. Other important sources include secondary lead industry, gray iron foundries, and petroleum refineries.

The important sources of cadmium emissions are primary copper industry, primary zinc industry, and iron and steel industry. These three sources contribute 89 percent of the total nationwide cadmium emission.

The important sources of POM emissions are agricultural burning, forest fires, open burning of solid wastes, incinerators, and coal refuse

TABLE 24. SOURCES AND QUANTITIES OF MERCURY EMISSION(6)

Source	Quantity, tons/yr
Mercury Mining	3
Chlorine Fluxing, Non-Ferrous Metals	55
Secondary Mercury	11
Organic Chlorine Chemical Manufacturing	70
Paint, Varnish, Lacquer Production	1
Instrument Manufacture	3
Electrical Apparatus Manufacture	3
Dental Preparation Manufacture	1
Use of Pesticides, Herbicides, Fungicides	19
Use of Pharmaceuticals	3
Laboratory Use of Mercury	51
Consumption of Paint	215
Incinerators	135
Sewage and Sludge Burning	11
Power Plant Boilers	174
Industrial Boilers	33
Residential and Commercial Boilers	5
TOTAL	793

TABLE 25. SOURCES AND QUANTITIES OF BERYLLIUM EMISSION(6)

Source	Quantity, tons/yr
Gray Iron Foundry	4
Beryllium Alloys and Compounds Production	5
Power Plant Boilers	101
Industrial Boilers	25
Residential and Commercial Boilers	9
TOTAL	144

TABLE 26. SOURCES AND QUANTITIES OF ASBESTOS EMISSION(6)

Source	Quantity, tons/yr
Asbestos Mining	5,610
Kraft Pulp Mill	15
Asbestos Products Manufacture	535
Use of Asbestos Construction Material	61
Spray on Steel Fire Proofing	15
Insulation Cement Application	25
Wear of Automobile Brake Linings[a]	583
TOTAL	6,844

[a] BCL estimate, based on 1.07 x 10^{12} vehicle miles traveled in 1969 in the United States, an average lifetime for brake linings at 27,500 miles, and asbestos emission at 0.03 lb/set of brake linings.(7)

TABLE 27. SOURCES AND QUANTITIES OF LEAD EMISSION(6)

Source	Quantity, tons/yr
Copper, Zinc, Lead Mining	345
Primary Copper	380
Primary Zinc	250
Primary Lead	714
Primary Nickel	246
Secondary Copper	520
Secondary Lead	2,020
Iron and Steel	150
Gray Iron Foundry	1,400
Petroleum Refining	1,250
Lead Alkyl Chemicals	810
Cd-Ni Battery Manufacturing	2
Incinerators	320
Power Plant Boilers	713
Industrial Boilers	141
Residential and Commercial Boilers	21
Gasoline Combustion	181,000
Gasoline Transfer	36
Lead Oxide Manufacturing	20
TOTAL	190,338

TABLE 28. SOURCES AND QUANTITIES OF CADMIUM EMISSION(6)

Source	Quantity, tons/yr
Primary Copper	652
Primary Zinc	1,040
Primary Lead	88
Secondary Copper	125
Iron and Steel	1,000
Non-Ferrous Alloys Production	3
Cadmium Paint Pigments Manufacture	11
Cadmium-Barium Plastics Stabilizers	3
Incinerators	95
TOTAL	3,017

TABLE 29. SOURCES AND QUANTITIES OF POM EMISSION(6)

Source	Quantity, tons/yr
Iron and Steel	43,380
Asphalt Industry	26,030
Petroleum Refining	2,170
Incinerators	230,453
Open Burning	526,843
Agricultural Burning	2,161,142
Forest Fires	1,433,712
Urban Fires	6,060
Coal Refuse Burning	193,500
Power Plant Boilers	24,148
Industrial Boilers	39,700
Residential and Commercial Heating	109,966
TOTAL	4,797,104

burning. These sources contribute 95 percent of the total nationwide POM emission. The majority of the POM emission originates from nonindustrial sources, such as agricultural burning, forest fires, and open burning of solid wastes.

Projections of Fine Particulate Emissions

Projections of fine particulate emissions by quantities and sources are given in Table 30 for the years 1975 and 1980. The data were taken from the Midwest Research Institute study,(1) in which the projections were made from 1968 as the base year. Two methods of projections are used. Method I assumes that there will be no change in the net control for each source, which would result in increases in emissions in proportion to increases in production capacity. Method II assumes that all sources will be controlled by 1980, and that increased utilization of the most efficient control devices will continuously increase the efficiency of control for fine particulates so that by the year 2000 the control efficiency will reach the efficiency of baghouse control, which is the best currently available method for fine particulates.

The projections indicate that the fine particulate emissions from industrial sources through 1980 will remain at a significant level even after the application of control to all such sources.

A substantial portion of fine particulate emissions originates from nonindustrial sources, for which no practical control method is available. These sources include mobile sources, such as automobile exhausts and tire wear, forest fires, cigarette smoke, ocean salt spray, and aerosol from spray cans. The emissions from these sources will continue to remain substantially at the existing levels through 1980. The fine particulate emission from these sources, excluding forest fire, in 1968 is estimated at 2.46×10^6 tons/yr.(1)

TABLE 30. PROJECTIONS OF FINE PARTICULATE EMISSION FROM INDUSTRIAL SOURCES(10)

		Nationwide Emission, 10^6 tons/yr	
Source	Method	1975	1980
Stationary Combustion	I	1.351	1.544
	II	0.994	0.815
Crushed Stone Industry	I	1.389	1.814
	II	1.186	1.137
Iron and Steel Industry	I	0.570	0.652
	II	0.392	0.354
Kraft Pulp Mills	I	0.405	0.484
	II	0.327	0.333
Cement Plants	I	0.227	0.273
	II	0.164	0.140
Hot Mix Asphalt Plants	I	0.205	0.250
	II	0.158	0.152
Ferroalloy Electric Furnaces	I	0.166	0.180
	II	0.074	0.008
Lime Plants	I	0.134	0.174
	II	0.094	0.086
Coal Preparation Plants	I	0.086	0.105
	II	0.061	0.047
Municipal Incinerators	I	0.051	0.061
	II	0.037	0.031
Fertilizer Manufacturing Plants	I	0.016	0.017
	II	0.012	0.010
Iron Foundries	I	0.015	0.016
	II	0.015	0.006
TOTALS	I	4.61	5.57
	II	3.51	3.12

REFERENCES

(1) Shannon, L. J., et al., "Particulate Pollutant System Study, Vol. II. Fine Particle Emissions", Final Report prepared for Air Pollution Control Office, Environmental Protection Agency under Contract No. CPA 22-69-104, Midwest Research Institute, August 1 (1971).

(2) "Air Quality Criteria for Particulate Matter", U.S. Dept. HEW, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration Publication No. AP-49, January (1969).

(3) "Background Information - Proposed National Emission Standards for Hazardous Air Pollutants: Asbestos, Beryllium, Mercury", Office of Air Programs, Environmental Protection Agency, Publication No. APTD-0753, December (1971).

(4) Rall, D. P., National Institute of Environmental Sciences, National Institutes of Health, HEW News Release, May 31 (1973).

(5) Engel, R. E., et al., "Environmental Lead and Public Health", Air Pollution Control Office, Environmental Protection Agency, Publication No. AP-90, March (1971).

(6) Goldberg, A. J., "A Survey of Emissions and Controls for Hazardous and Other Pollutants", Air Pollution Technology Branch, Technology Division, Office of Research and Monitoring, Environmental Protection Agency, February 26 (1973).

(7) Crowder, J. U., and Wood, G. H., "Control Techniques for Asbestos Air Pollutants", Environmental Protection Agency, Publication No. AP-113, February (1973).

SECTION XII

EXPANDED DRINKING WATER CONTAMINATION

Nature of the Problem

Drinking water for human needs, is derived from the same sources that supply water needs for human enterprises - industry, power production, irrigation and the like. These sources, unfortunately are also the receptors of pollutants from the same enterprises. Current USPHS drinking water standards (1962) provide impurity limits for only a relatively few pollutants under the classifications of bacteriological, physical, chemical and radioactive characteristics. Water meeting these standards is generally accepted by the public as safe.

Several events of the past decade have raised new concerns about the relative safety of drinking water. One is that methods of detecting constituents in water have become more sophisticated permitting even lower concentrations of contaminants to be recognizable. Another is the increasing awareness of the extent to which the environment is polluted, i.e., new recognition of the sources, amounts, pathways, and effects of specific pollutants. Coupled with the latter is the realization that the numbers of chemical entities synthesized, produced and utilized in the U.S. has been increasing dramatically. Since these substances in most cases eventually find their way into water supplies, a reexamination of drinking water safety appears to be a necessity. The problem is intimately tied to problems of trace metals, pesticides, fine particulates, and longer term health effects of these.

Projection

Water Usage and Treatment

Table 31 shows the situation in the U.S. with respect to municipal water supply. A projected increase between 1960 and 1980 of from 20 to 33.5 billion gallons per day will serve domestic, public, commercial and

TABLE 31. MUNICIPAL WATER SUPPLY IN THE U.S. (1960-1980) (1,2,3)
(Billion gallons per day)

Year	Domestic*	Public*	Commercial*	Industrial*	Total Municipal
1960	8.6	3.0	3.8	4.6	20
1965	10.2	3.6	4.5	5.4	23.7
1980	14.4	5.0	6.4	7.7	33.5

* Based on estimated 43, 15, 19, and 23 percent of total municipal use respectively for domestic, public, commercial, and industrial.

industrial segments comprising municipal users. Municipal users in turn represent about 8 percent of water usage for all purposes in the U.S. Per capita water usage of municipal water has not changed drastically since about 1955 and is in the range of 150-160 gallons per capita per day.

Apparently not all of the municipal water volumes shown received treatment, or at least not treatment to the same degree. Domestic and public portions no doubt receive treatment according to drinking water standards requirements. The commercial and industrial volumes may not require this level of treatment depending upon the usage.

The percentage of the U.S. population served by municipal water supply systems has increased over the same time period as follows:(4)

1960	75.2
1970	82.2
1980	90.7

This suggests two environmental factors: (1) there is still a significant population fraction relying on untreated sources (wells, e.g.) which may or may not have been exposed to the extensive range of pollutants known to be released each year from production-consumption activities; and, (2) the volumes of sludge from water treatment which require disposal (and which in themselves constitute a disposal problem) will continue to rise through 1980. This quantity is in excess of one billion pounds a year at present. Disposal of the latter into streams is no longer considered acceptable practice.

Contaminants

The number of different types of contaminants in water sources from which drinking water is derived is large. The awareness of just how large has been developing in the past decade as a consequence of (1) studies of sources and pathways to the environment of emissions to the air, water, and land from all of man's activities and natural phenomena

(weathering of earth's crust, volcanoes, lightning-induced forest fires, etc.) and (2) increasingly more sophisticated detection instrumentation. The types of contaminants include organics, inorganics, biologicals, radioactive elements, low taste and odor threshold compounds.

Organics. Microquantities of organic compounds have been observed in sea water (nearly 500!)(5) and in tap water(6), facts which attest to the widespread contamination of the environment. Sources include effluents from chemical manufacture, treated municipal waste waters containing refactory organics (non-biodegradable) - some of which are known carcinogens like PCB's(7), accidental spills of oils and chemicals, and agricultural runoff which contributes organic pesticides, herbicides, fungicides and many other plant growth chemicals. USPHS drinking water standards (1962) do not specify limits on organics (other than phenols, carbon chloroform extracts, and alkyl benzene sulfonate) except to indicate that water "shall not contain impurities in concentrations which may be hazardous to the health of consumers". Recommended changes to the 1962 standards do provide limits for a number of pesticides(8).

Organic residues in drinking water range at about the 10 ppm level. Detection of specific compounds, however, is difficult as these may be in the parts per billion or trillion range.

Inorganics. As with organics, there is no dearth of sources of inorganic contaminants. Natural sources accrue from weathering and leaching of constituents of the earth's crust. The mining and processing of fossil fuels and sulfide mineral ores results in mine drainage leachates (acids and heavy metals solubilized by the acid). Automotive exhaust, air emissions, and landfill leachates are other sources.

Recently, very high concentrations of asbestos fibers, suspected of causing stomach and intestinal cancer, were discovered in drinking water supplies in Minnesota. Presumably the source is from taconite tailings dumped into Lake Superior.(9) Asbestos can also get into water from asbestos-containing pipes for water transport and from natural rock formations.

Mercury sources in the Great Lakes from the chlor-alkali industry are well documented, as is the conversion of mercury to its more toxic organometallic form - methyl mercury.(10)*

Nitrates in water are known to be a problem for infants and may be out of control in rural areas due to fertilizer runoff.

USPHS drinking water standards cover a number of inorganic elements (As, Ba, Cd, Cr, Cn, F, Pb, Se, Ag, Mn, Cu, Fe, SO_4, Zn, Cl). Organometallics are not covered.

Radioactivity. Radioactive substances from fallout associated with nuclear testing has been of concern in the past. Tritium, radium, and strontium are elements of current interest.(11) USPHS standards exist only for the latter two.

Taste and Odor. Somewhat related to the organics problem, there are many compounds which find their way into water which have extremely low taste and odor thresholds, i.e., at very low concentrations their presence can be detected. Control is difficult.

Biologicals. Between 1961 and 1970, there were 130 outbreaks of diseases or chemical poisoning in the United States attributed to contaminated drinking water; these outbreaks affected ~46,000 persons and resulted in 20 deaths.(12) These included 30 due to infectious hepatitis, 39 attributed to gastroenteritis (of undetermined etiology), 23 from salmonella (14 by *S. typhi*), and 19 attributed to *Shigella* (mostly *S. Sonnei*). At least 85 percent of all the outbreaks were due to pathogenic microbes, and 62 percent and 23 percent was due respectively to bacterial and viral diseases. While these cases were mainly due to

---

* A 1972 episode reported in this reference occurred in Iraq involving contamination of water supplies by mercury-insecticide treated wheat. It is said to have resulted in death to thousands.

negligence, there is also a problem that current technology does not provide complete removal or at least quick analysis of viruses or pathogenic bacteria. Viruses and salmonella have been found to pass through conventional waste treatment plants, and therefore, there microbes are possible hazards to drinking water supplies.

The removal or disinfection of viruses has been an area of interest in both water and waste treatment. The applications of flocculation and coagulation, lime precipitation, and sand filtration will remove approximately 80-94 percent,(17) 60-99 percent,(14) and 1-49 percent(15) of the polioviruses, respectively. Conventional water treatment will not completely remove viruses. Chlorine is effective at 9 mg/ℓ if combined residual chlorine is present for an exposed time of 30 minutes or at 0.5 mg/ℓ if combined residual chlorine is present for 7 hours.(16) With the use of sodium hypochlorite, Scarpino, et al.(17) found that OCl^- at a pH of 6 was 130 times more effective on E. Coli than polioviruses, and at a pH of 10 was 50 times more effective on polioviruses than E. Coli. Ozonation as a disinfectant requires 15 mg/ℓ of ozone at 5 minutes exposure time to inhibit viral activity.(18) It appears that an economical and simple approach for pathogenic viral and bacterial removal is achievable.

Control

One of the primary needs associated with control of drinking water contaminants is the establishment of the levels that given substances will be acceptable in water. The expenditures of large sums of money to bring contaminants down to levels that have no scientific basis for their existence would not be wise.

Reuse of municipal wastewaters for drinking purposes in certain water short locales is not too far in the future (5-10 years?). This possibility alone requires that effort be initiated now to develop standards based on health effects data. Even if reuse in this way is not widely practiced in the U.S., it is apparent that a form of reuse has been in existence all along, i.e., by downstream withdrawal of water contributed by an upstream user.

REFERENCES

(1) Wollman, N. and Bonem, G. W., pp 19, 54, 181, The Outlook for Water, The Johns Hopkins Press (1971).

(2) Todd, K. D., (editor) pp 220-222, The Water Encyclopedia, Water Information Center (1970).

(3) Metcalf and Eddy, Inc., pp 25-26, Wastewater Engineering, McGraw Hill (1972).

(4) "Regional Construction Requirements for Water and Wastewater Facilities, 1955-1967-1980", U.S. Dept. of Commerce Publication (1967).

(5) Daursma, E. K., "The Dissolved Organic Constituents of Sea Water", Chemical Oceanography, Vol. II, edited by Riley and Skinner, Academic Press (1965).

(6) Crossland, J. and Brodine, V. "Drinking Water", Environment, 15(3), 11-19 (1973).

(7) Choi, P.S.K., Nack, H., Flinn, J. E., "Distribution of Polychlorinated Biphenyls in an Aerated Biological Oxidation Wastewater Treatment System", Bull. Envr. Contamination and Toxicology (to be published).

(8) Water Quality and Treatment, American Water Works Association (3rd Edition), p 47, McGraw-Hill (1971).

(9) Clean Air and Water News, 4(4), 307, Commerce Clearing House (January 25, 1973).

(10) Reimers, R. S., "Sorption of Mercury on Synthetic and Natural Sediments", PhD Dissertation, Vanderbilt University (August, 1973).

(11) Robeck, G.G., personal communication with project staff.

(12) Taylor, A. J., et al., "Outbreaks of Waterborne Diseases in the U.S.", J. Infectious Diseases, 125, 329 (1972).

(13) Thorup, R. T., Nixon, F. P., Wentworth, O. F., and Sproul, O. J., "Virus Removal by Coagulation with Polyelectrolytes", J. AWWA, pp 97-101 (February, 1970).

(14) Thayer, S. E. and Sproul, O. J., "Virus Inactivation in Water-Softening Precipitation Processes", J. AWWA, Vol. 58, pp 1063 (August, 1966).

(15) Robeck, G. G., Clarke, N. A., and Dostal, K. A., "Effectiveness of Water Treatment Process in Virus Removal", J. AWWA, Vol. 54, pp 1275 (October, 1962).

(16) Kelly, S. and Sunderson, W. W., "The Effect of Chlorine in Water on Enteric Viruses", Amer. J. Public Health, Vol. 50, pp 14 (1960).

(17) Scarpino, et al., "Projects of the Municipal Technology Branch through June, 1972", EPA, Washington, D.C., EPA-R-2-72-080 (September, 1972).

(18) Pavoni, J. L., et al., "Virus Removal From Wastewater Using Ozone", Water and Sewage Works, Vol. 119(12), pp 59 (1972).

SECTION XIII

IRRIGIATION (IMPOUNDMENT) PRACTICES

Nature of the Problem

With the current and projected population levels in the U.S. and abroad, the most productive utilization of agricultural land is essential to meet rising food demand. Irrigation of arid and semi-arid regions of the U.S., to meet agricultural and land development needs, has grown the ten-fold in the past 70-75 years.

Environmental impacts from irrigation accrue from the salt concentration which naturally occurs as the pure water is extracted by plants and evaporates to the air. Return of these saline waters to a receiving stream or underground water supply provides a detrimental effect. Other impacts result from the construction and operation of impoundments to provide irrigation waters.

The sheer magnitude of this problem in terms of (1) acreage and water quantities affected, (2) growth in the practice and (3) complexity of the impacts raises this as a future problem of national importance.

Projection

The application of irrigation practices to arid lands has tended to rise at a steady rate since 1940. From Figure 4, the land area being irrigated has increased 100 percent from 1944 to 1970 and is forecasted to increase about the same rate to 1980.(1) Even though the percentage of water utilized for irrigation has dropped from a high of 52 percent of the total water usage in the United States in 1940 to a predicted low of 37 percent in 1975, the absolute magnitude of water needed for this purpose has more than doubled in the same period (see Table 32). Irrigation as a practice appears to have been increasing at the rate of 2.3 billion gallons a day per year since 1960.(2) Along with the steady increase in water consumption for irrigation, the water needs in industry and power sectors

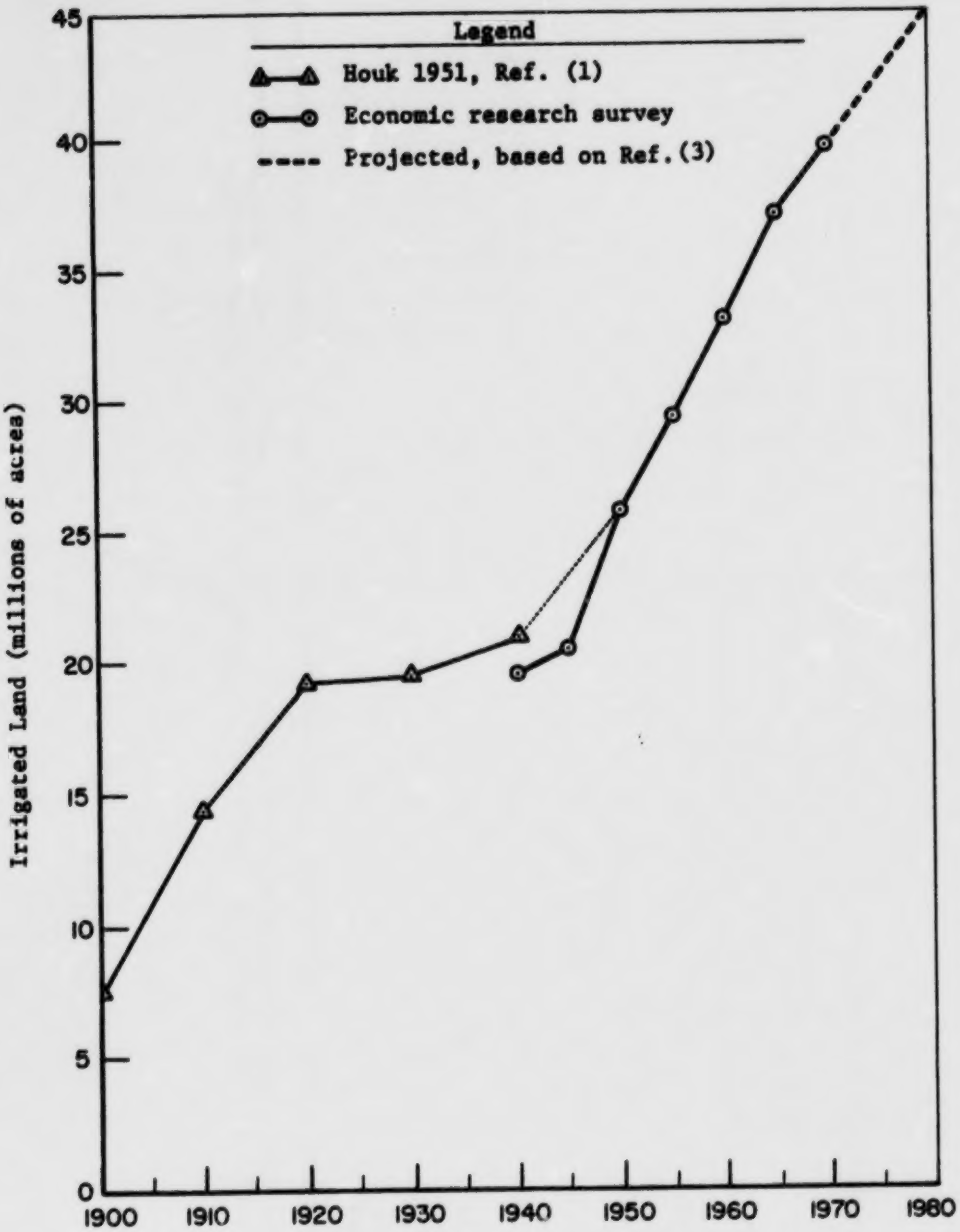


FIGURE 4. IRRIGATED LAND IN THE UNITED STATES

TABLE 32. UNITED STATES: ESTIMATED WATER USE, 1900-1975
(Billions of Gallons; Daily Average)(2)

Year	Irrigation (Billions Gallons) per day	Irrigation (% Total)	Power and Industry (Billions Gallons) per day	Power and Industry (% Total)	Total (%>) (Billions Gallons) per day
1900	20.2	50	15.0	37	40.2
1920	55.9	62	28.0	30	92.3
1940	71.0	52	51.2	38	135.4
1960	135.0	43	149.5	48	312.5
1965	148.1	41	181.9	51	359.5
1970	159.0	39	210.8	52	404.5
1975	169.7	37	246.4	54	453.1

*All other uses only constituted between 13 percent to 9 percent of all water used from 1900 to 1975. This constituted 5 billion gallons/day to 37 billion gallons per day.

have increased at an even faster pace (Table 32) creating an even greater demand for water. The practice of irrigation has caused, and could magnify, four major environmental impacts:

(a) A lowering of irrigation water quality due to salinity increases

(b) A decrease of river water quality due to lower river flows

(c) A reduction of the abiotic and biotic quality of estuaries due to decreased river flow.

Salinity and Irrigation Water Quality

Salinity constitutes the principal stressor contributing to water quality impairment from irrigation. As the water demands for irrigation, energy resource development, and industrial production grow, sources of quality water will become scarce, particularly in certain water deficient regions. In order to meet demand in the latter areas, either the application of desalination technology to reduce salinity will be required or irrigation water of lower quality will have to be used. The accumulation in salinity in water returning from irrigated land has been shown to increase by a factor of four just eight years between 1957 and 1965 as illustrated in Table 33, and there does not appear to be any noticeable variation for the near future.(2) In 1957, the return irrigation waters had a factor of four lower salt output than the input irrigation water itself. But, by 1963 and 1964 salt output of the return irrigation water was about the same as the input irrigation water. However, since the quantity of return water (after losses) is much less the salinity level is significantly greater than the input water used for irrigation. Table 34 reflects a similar situation for the chemical composition of the inflow and outflow salt content from irrigation for the Yakima Valley.

The chemical constituents in the saline irrigation return flows (unconsumed water) of Yakima Valley, Washington, have been examined by Sylvester and Seabloom.(5) They found higher levels of salinity and hardness for underground return flow of irrigation waters, but lower coliforms,

TABLE 33. ACRES OF IRRIGATED LAND, INPUTS AND OUTPUTS OF WATER AND SALT FOR IRRIGATED LAND FROM 1957 to 1964 FOR COACHELLA VALLEY, CALIFORNIA(2)

Year	Irrigated Lands (acres)	Inputs to Irrigated Lands			Outputs from Irrigated Land		
		Water (acre-ft)	Salt		Water (acre-ft)	Salt	
			(tons/acre-ft)	(tons)		(tons/acre-ft)	(tons)
1957	57,329	299,590	1.234	370,000	32,578	3.065	100,000
1959	55,527	358,641	0.972	349,000	47,188	3.530	167,000
1961	53,990	366,315	1.066	390,000	75,597	3.666	277,000
1963	57,773	370,014	1.058	391,000	110,627	3.640	402,000
1965	59,870	341,165	1.193	407,000	124,128	3.423	425,000

TABLE 34. SALT BALANCE, YAKIMA VALLEY, WASHINGTON(5)

Constituent	Inflow tons	Outflow tons	Net tons	Ratio O/I
Cations:				
Ca	33,600	73,000	+ 39,400	2.17
Mg	16,900	33,400	+ 16,500	1.97
Na	13,700	60,500	+ 46,800	4.42
K	4,700	7,800	+ 3,100	1.66
Anions:				
HCO_3	190,000	430,000	+240,000	2.26
Cl	3,400	22,000	+ 18,600	6.48
SO_4	18,200	65,000	+ 46,800	3.57
NO_3	3,600	16,300	+ 12,700	4.53
TOTALS	281,100	708,000	+426,900	2.52

temperatures, dissolved oxygen, pH, COD (chemical oxygen demand), and turbidity as compared to surface return flow as illustrated in Table 35. In all cases except the coliform counts (a measure of microbial activity) and dissolved oxygen, all chemical parameters were observed to increase in concentration after the application of water to irrigation lands.

Irrigation return flows are a source of contamination of reservoirs from whence irrigation waters are derived. Table 36 illustrates this fact for the Hoover Reservoir. Note that the major sources of salt build up in the reservoir are natural sources, irrigation, and evaporation, respectively.

The dangers of toxic contaminants disrupting the natural ecosystem are particularly acute in arid regions. Consequently, the fate of trace contaminants becomes an important interest for ecologists and environmentalists. Table 37 suggests probable sinks of various abiotic and biotic parameters of pollution after irrigation.

Crops have tolerance limits with respect to soil water salinity. These limits vary widely depending upon the crop. Barley, cotton, sugar beets, and tomatoes can tolerate fairly high levels of salt (75,000 mg/l TDS) whereas citrus crops, berry plants, potatoes and corn have much lower tolerance. A low chloride level in particular is necessary for the latter crop group.

Toxic contaminant levels have been established for irrigation waters and are shown in Table 38.(1) The effect on crops and soils of various types of irrigation water quality has and is going to play a major role especially with respect to trace contaminants and salinity.

Reduced River Flow

With the growth in irrigation practice and associated impoundments (and for that matter impoundments for hydroelectric power) the potential for effects from reduced river flow will increase. The reduction of river flow due to use of impoundments which supply water for irrigation has been found to change the existing environmental conditions and can often be shown to decreases the assimilative waste capacity of lower water basins. The parameters involved are temperature, dissolved oxygen, microbial activity,

TABLE 35. COMPARISON OF IRRIGATION WATER AND DRAINAGE WATER, YAKIMA VALLEY, WASHINGTON

Constituent	Applied Water[1]	Underground(6) Drains(6)	Surface Drains[1]
Salinity (EC μmhos[3])	83.0	420.0	283.0
Temperature °C	16.0	13.3	17.9
Oxygen, mg/l	10.2	6.8	9.0
pH	8.1	7.7	8.2
COD, mg/l[4]	7.0	9.0	10.0
Hardness as $CaCO_3$	46.0	186.0	121.0
Turbidity units	37.0	12.0	130.0
Total PO_4, mg/l	0.32	0.86	0.83
Coliforms per 100 ml	1,070.0	103.0	10,600.0

[1] Average for 7 stations.

[2] Average for 5 stations.

[3] Electrical conductance in μmhos per cm at 25 °C.

[4] Chemical oxygen demand.

TABLE 36. INCREMENTAL SALT CONCENTRATION ATTRIBUTABLE TO SPECIFIC SOURCES, COLORADO RIVER AT HOOVER DAM(7) (1942-1961 PERIOD OF RECORD ADJUSTED TO 1960 CONDITION)*

Sources	Total Dissolved Solids mg/l
Natural Sources	
Diffuse sources	274
Point sources (mineral springs, wells, etc.)	69
Irrigation	253
Municipal and Industrial Sources	10
Water Exports	22
Evaporation and Phreatophytes	97
TOTAL	725

* Based on data from: USGS Professional Paper 441, Water Resources of the Upper Colorado River Basin, 1965; USDI, Progress Report No. 3, Quality of Water, Colorado River Basin, January, 1967; FWPCA records on open files.

TABLE 37. PROBABLE FATE OF MUNICIPAL AND INDUSTRIAL POLLUTANTS AFTER IRRIGATION(2)

Pollutants of Municipal and Industrial Origin	Probable Fate After Irrigation Use
Total dissolved solids Sodium Chlorides Sulfates Boron	Reappears in surface and subsurface return flows in increased concentrations
Heavy metals Phosphorus	Precipitated and fixed in soil; some may persist in surface return flow
Bacteria	Removed in soil; some may persist in surface return flow
Radioactivity	Removed in soil; taken up by crops; some may persist in surface return flow
Pesticides and exotic organic chemicals	Many removed in soil; will persist in surface return flow; some may possibly persist in subsurface return flow

TABLE 38. TRACE ELEMENT TOLERANCES FOR IRRIGATION WATERS(1)

Element	For Water Used Continuously on all Soils mg/1	For Short-Term Use on Fine Textured Soils Only mg/1
Aluminum	1.0	20.0
Arsenic	1.0	10.0
Beryllium	0.5	1.0
Boron	0.75	2.0
Cadmium	0.005	0.05
Chromium	5.0	20.0
Cobalt	0.2	10.0
Copper	0.2	5.0
Lead	5.0	20.0
Lithium	5.0	5.0
Manganese	2.0	20.0
Molybdenum	0.005	0.05
Nickel	0.5	2.0
Selenium	0.05	0.05
Vanadium	10.0	10.0
Zinc	5.0	10.0

sedimentation, and trace contaminants. Two key parameters are temperature and dissolved oxygen.

Following the construction of an impoundment, a change in average river water temperature will occur. This change can have either a negative or positive impact. Since impoundments are commonly stratified, the temperature of the deep, cold, and relatively undisturbed bottom region of the reservoir (hypolimnion) tends to be fairly cool when compared to the surface, warm, and relatively disturbed region of a reservoir which is exposed to ambient air (epilimnion). Under low flow conditions the stream temperature will equilibrate rapidly with the ambient terrestial surroundings. Also since the river turbulence will be diminished, less oxygen will be absorbed. Consequently, the dissolved oxygen of the stream will be exhausted more readily. Any influent organic wastes with its associated biological oxygen demand will further reduce the ability of the river to reaerate itself. These effects are illustrated in Figure 5.(8,9)

Other water quality parameters effected by decreased river flow are decreases in nutrient levels due to sedimentation, increase in the influences of runoff contaminants such as pesticides, herbicides, fungicides, fertilizers (phosphates, nitrates, feedlot wastes, and mineral leaching), and decreases in river water quality due to containing low dissolved oxygen levels in the cooler inflow of hypolimnion waters. The reduced dilution capacity due to low river flow can also result in salinity increases.

Downstream Estuary Impacts

Decreased freshwater inflows are known to have a most influential impact on estuarine environments. The reduction of freshwater inflow will increase the salinity intrusion, increase the sedimentation of river suspended matter in its headwaters instead of in the estuary, decrease the dissolved oxygen, decrease the specieis diversity of the fish, and decrease the specific heat of the estuarine water due to increased salinity.(10) Because estuaries encompass large land areas, the combined effects can be quite profound. Figures 6 and 7 show examples of the effects of salinity increases on the number of fish species and dissolved oxygen level.(11,12)

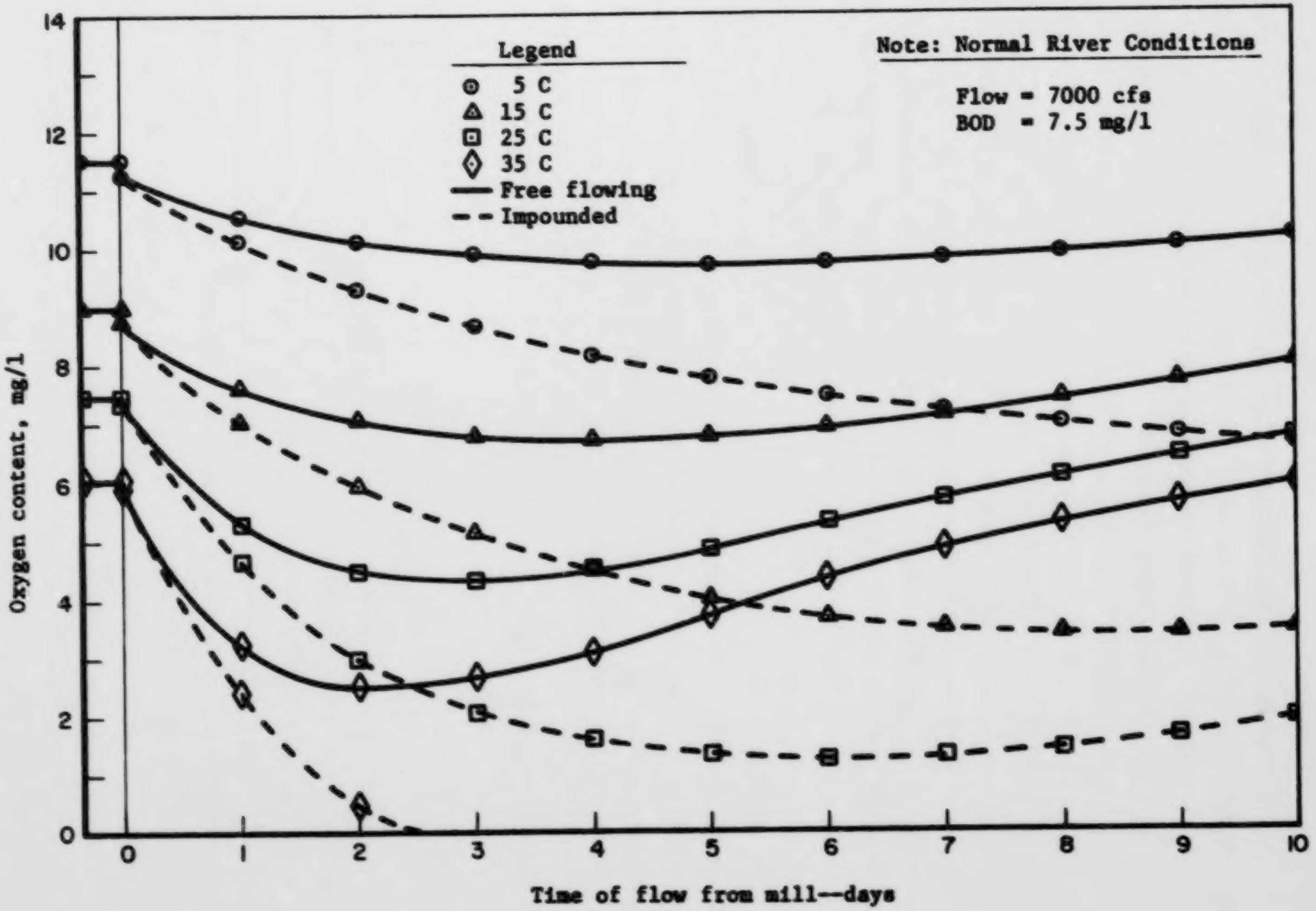


FIGURE 5. TIME AND TEMPERATURE EFFECTS UPON OXYGEN CONTENT (SAG) IN FREE-FLOWING AND IMPOUNDED RIVERS

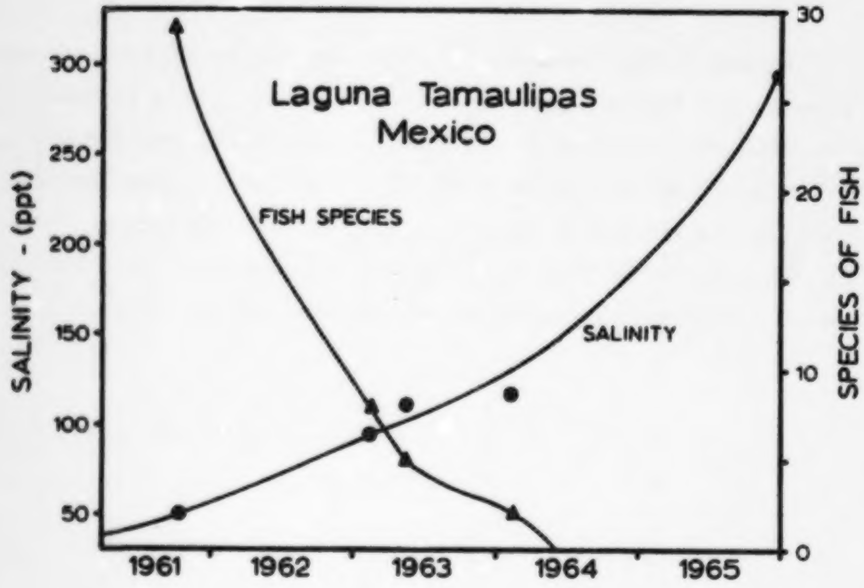


FIGURE 6. SALINITY IN PARTS PER THOUSAND AND NUMBER OF FISH SPECIES IN THE LAGUNA TAMAULIPAS, MEXICO, DURING 1961 THROUGH 1965(10)

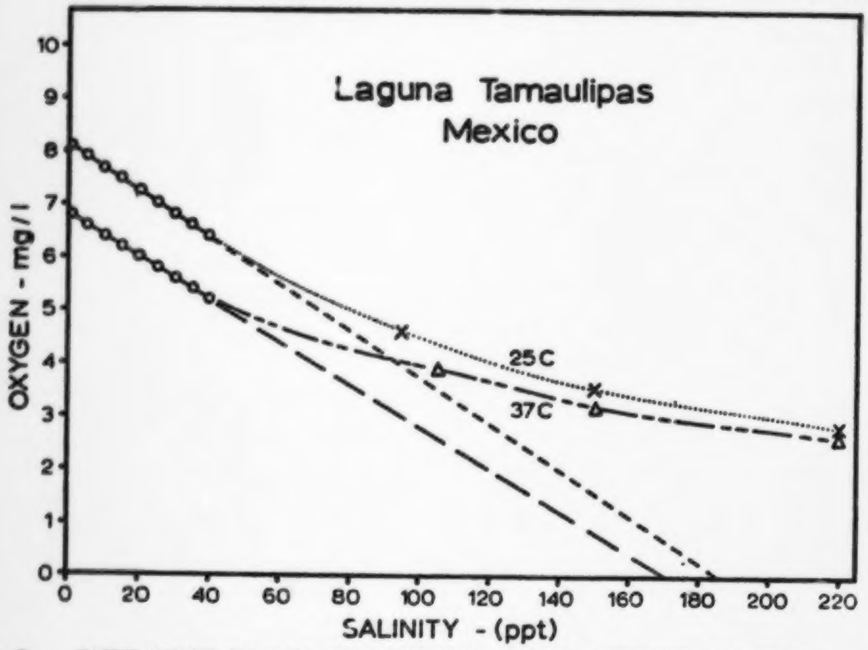


FIGURE 7. SATURATION VALUES OF DISSOLVED OXYGEN VERSUS SALINITY.

In the 1960s, Copeland(10) reported on the effects of reduced freshwater flow in the fishing industry in south Texas. A 50 percent reduction in commercial fishing occurred at Aransas and Corpus Christi Bays, Copeland and Hoese(13) also noted the destruction of one of the largest oyster producing industries in the world due to the reduced freshwater inflow into Galveston Bay. It was postulated that increased salinities which in turn triggered increased temperature fluctuations initiated the loss.

References

(1) Law, J. P., and Witherow, J. L., "Water Quality Management Problems in Arid Regions", Water Pollution Control Research Series 13030 DYY 6/69 (October, 1970).

(2) McGauhey, P. H., Engineering Management of Water Quality, McGraw-Hill Book Company, New York (1968).

(3) Private communication from USDA.

(4) Smith, J. F., "Imperial Valley Salt Balance", Public Information Office, Imperial Irrigation District, El Centro, California (1966).

(5) Sylvester, R. O., and Seabloom, R. W., "Quality and Significance of Irrigation Return Flow", J. Irrig. and Drain. Div. ASCE, 89 (IR3): 1-27 (September, 1963).

(6) Bernstein, L., "Quantitative Assessment of Irrigation Water Quality", Water Quality Criteria, ASTM STP 416, Am. Soc. Testing Materials, p 51 (1967).

(7) Federal Water Pollution Control Administration, "Cost of Clean Water", Volume II, Detailed Analysis, USDI (1968).

(8) Krenkel, P. A., Eckenfelder, W. W., Gloyna, E. F., and Fruh, E. G., Stream Analysis and Thermal Pollution, Volume II, World Health Organization, Regional Office for Europe, Copenhagen, Denmark, p 217 (June, 1968).

(9) Driver, E. E., and Krenkel, P. A., "The Effects of Modifications of the Flow Regime on the Waste Assimilative Capacity of the Coosa River", Technical Report No. 5, Sanitary and Water Resouces Engineering, Dept. of Civil Engineering, Vanderbilt University, Nashville, Tennessee (1965).

(10) Copeland, B. J., "Effects of Decreased River Flow on Estuarine Ecology", Journal Water Pollution Control Federation, 38 (11), 1831-1839 (November, 1966).

(11) Copeland, B. J., "Environmental Characteristics of Hypersaline Lagoons", Contributions in Marine Science, 4, 208-218 (July, 1967).

(12) Copeland, B. J., and Jones, R. S., "Community Metabolism in Some Hypersaline Waters", The Texas Journal of Science, 17 (2), 188-205 (June, 1965).

(13) Copeland, B. J., and Hoese, H. D., "Growth and Mortality of the American Oyster, Crassostrea Virginica, in High Salinity Shallow Bags in Central Texas", Publ. Institute of Marine Science, Texas Vol. II, pp 149-158 (November, 1966).

SECTION XIV

ACKNOWLEDGMENTS

The assistance of numerous individuals was received in compiling, ranking, and developing background information on the problems identified. At NERC-Cincinnati, Francis Middleton contributed his time along with Norbert Schomaker, Robert Stenberg, Gordon Roebeck, Leland McCabe, Jerry Stara, Clarence Clemons, Gerald Berg, Robert Bunch, Robert Dean, James Symons, and Carl Brunner. At NERC-Research Triangle Park, John F. Finklea cooperated in arranging interviews with John Smith, Gene Sawicki, John Moran, Tony Colucci, Tom Houser, and Gene Tucker. Office of Research and Development personnel who participated (or provided alternates) included Ken Bridboard, Alphonse Forziatti, Paul Gerhardt, Dave Graham, Dick Harrington, Don Holmes, Bill Lacy, Harry Landon, Robert Payne, Ed Royce, Herb Wiser, Bill Upholt, Larry Plumlee, Ed Shuck, and Wayne Ott. Del Barth, Director NERC-Las Vegas, and Farley Fisher, Larry Rosinski and Begina Carroll of the Office of Toxic Substances also managed to find time to provide input.

Battelle participants included Bob Reimers, Ron Byrd, Howard Reiquam, Art Levin, Dave Morrison, Ray Smithson, Byung Kim, Ed Stambaugh, Charles Peet, Bill Sheppard, Tom Carroll, Gil Raines, Dave Stutz, Gerry Nehman, Paul Lerro. Many others responded to requests for input of ideas, thoughts, and evaluations.

APPENDIX A

IDENTIFICATION OF CANDIDATE PROBLEMS

Candidate future problems were developed using these steps:

(1) A preliminary listing of problem statements (this Appendix) was developed by consolidating the results of three independent searches of broad categories and specific sectors of human activity

(2) Ranking factors were developed to aid in screening and prioritizing the candidate problems.

(3) Ten "most serious" problems (or combinations) were tentatively identified from the preliminary list through application of the ranking procedure

(4) Revisions to the initial selection were made after consultation with EPA and further study of the problem definitions. These revisions resulted from combination, readjustment of title, or expansion of the problem definitions

(5) The initial ranking factors were refined, weighted by a modified Delphi technique and reapplied to the final version of the ten "most serious" problems to develop a numerical ranking to the most serious" problem set.

Development of Preliminary List

The methodology employed for developing future problem candidates relied principally on the rapid screening of three broad categories of human activity combined with a review of readily accessible literature.

Emphasis was placed on identifying and interviewing persons knowledgeable in selected activity sectors of the three categories. The sectors reviewed resulted from structuring of the three activity categories:

(1) technical production; (2) environmental; and, (3) societal change and/or trends. The search for problems was conducted independently in each activity category.

Technical Production Activity

The sectors for review in this category were selected by reference to the Standard Industrial Classification Manual. Only broad sectors (one or two digit SIC codes) could be dealt with in the time allowed, e.g., agriculture, mining, construction, and selected manufacturing areas. Source personnel for this search were drawn primarily from within Battelle-Columbus--chiefly persons with wide experience in specific sectors. Group meetings were held pertaining to each sector, e.g., agriculture, selecting attendees so as to cover several facets of the activity. Technology and marketing trends were reviewed and possible environmental consequences were identified for consideration.

Environmental Activity

The idea of searching within this category was to take advantage of the already well structured U.S. environmental effort and use the existing base of information to project new problems. Among the sectors reviewed within this activity category were: (1) environmental legislation; (2) ongoing research in air, water, and land media; (3) health effects and specific pollutants; (4) pollution control technology; (5) monitoring and standards; and (6) transport processes.

Sources which were probed for information in these sectors included:

(1) Selected Program Element Managers, Office of Research and Development, EPA
(2) Deputy Director, Selected Laboratory Managers and Branch Chiefs, NERC-Cincinnati
(3) Selected Laboratory Managers, Branch Chiefs and other staff personnel, NERC-Research Triangle Park

(4) Director and selected staff, NERC-Las Vegas

(5) Battelle-Columbus
    (a) Selected staff in environmental sectors
    (b) BCL staff at large through mechanism of seminar and newsletter

(6) Literature (published and unpublished reports, surveys, problem listings).

The constraint of time necessarily limited the search for problems to primarily BCL and EPA sources.

Societal Changes/Trends

Within this category, specific sectors for searching were initially delineated by means of internal discussions and reference to the literature. These included:

Demographic
Crime
Medical Science
Education
Social
Economics
International
Technological
Government
Urban
Labor.

For each sector, specific trends were identified, e.g., decreasing birth rate, increase in crime, increased therapeutic and non-therapeutic drug use. These trends were examined for possible sources of environmental or pollution problems.

Problems versus Stressors

It was found useful as work under this contract proceeded to differentiate between the terms "pollution problem" and "environmental stressors". Originally (BCL proposal dated March 2, 1973) it was planned to use these terms interchangeably and defined as "any general class or specific substance, effect, or condition which has an adverse impact on man or his environment". As the search progressed, however, it became apparent that two kinds of problems were generally under discussion; (1) specific pollutants (SO_x, asbestos, aeroallergens, freon, heat energy) and (2) general pollution problems wherein more than one pollutant was involved. Thus, the term stressor was reserved for the more specific pollutants or class of pollutant - chemical compound or element, biological agent or physical substance - which are components of most problems. Thus, for the initial list of 10 most serious problems, an analysis revealed that the following stressors were frequent components.

Stressor	Occurrence Ten "most serious" Problems
Heavy metals	9
Toxic organics	9
Fine particles	8
Inorganic salts	7
Mercurials	7
Arsenic and its compounds	7
Sulfate and nitrates	7
Toxic organometallics	7
Suspended solids	6
Taste and odor	6

The preliminary list of problem statement titles is given in Table A-1, arranged in one of nine categories. The number preceding each title corresponds to the numbered problem statement abstracts which follow the table. The latter are slightly edited versions of the preliminary listing originally submitted to EPA (May 15, 1973).

TABLE A-1. PRELIMINARY LIST OF PROBLEMS BY AREA AND TITLE

- POLLUTION CONTROL RESIDUES

  A-1* Disposal of Secondary Treatment Sludges
  A-2 Sludges, Liquid, and Solid Residues from Pollution Control
  A-3 Impacts from Flue Gas Treatment
  A-16 Disposal of Waste Oils from Oil Spills and Other Sources
  A-20 Crankcase Oil Recycling
  (See also A-15, A-37, A-38, A-43)

- INDUSTRIAL PRODUCTION-CONSUMPTION RESIDUES

  A-5 Oil Well and Other Waste Brines
  A-6 Coal Cleaning Residues
  A-7 Waste Industrial Acids
  A-25 Metallic Machining Sludges
  (See also A-12, A-14, A-16, A-21, A-31, A-32, A-39)

- ENERGY SUPPLY

  A-14 Electric Power Generation
  A-17 Bulk Shipment of Liquefied Gases
  A-31 Oil Shale Production
  A-35 Pipeline Construction
  A-42 Geothermal Power
  A-48 Underground Mining
  A-49 Coal Gasification
  A-50 Radioactive Wastes
  (See also A-8, A-9, A-16, A-18)

- TOXIC AND HAZARDOUS SUBSTANCES

  A-10 Toxic Substances in Recycled Animal Waste
  A-23 Inorganic Toxic Contaminants
  A-26 Chlorinated Hydrocarbons, Pesticides, Herbicides, and Fungicides

---

* This number refers to specific problem statements following table.

TABLE A-1. PRELIMINARY LIST OF PROBLEMS BY AREA AND TITLE (Continued)

A-28 Fluorinated Hydrocarbons
A-29 Carcinogens
A-30 Incineration of New Materials
A-37 New Landfill Technology
A-45 Urban Pesticide Use
A-46 Crop Dusting and Spraying
A-51 Plant and Animal Growth Promoters
A-55 Household Products
(See also A-43, A-44, A-47, A-50, A-56)

- AIR POLLUTION

A-9 Fine Particulates in Air
A-11 Automotive Exhaust
A-12 Catalytic Convertors for Autos
A-40 Spark Sources
A-47 Sulfur Dusts
A-34 Spray Irrigation Pathogens
A-39 Solvents from Coating and Dyeing Technology
A-53 Aeroallergens
A-56 Household Dusts
(See also A-30, A-46, A-22)

- WATER POLLUTION

A-4 Effects from Dredging
A-8 Acid Mine Drainage
A-13 Nondegraded Organics from Secondary Treatment
A-15 Drinking Water Treatment
A-18 Bulk Shipment of Liquid Chemicals and Fuels
A-19 Spilled Petrochemicals
A-36 Deicing of Roadways

TABLE A-1. PRELIMINARY LIST OF PROBLEMS BY AREA AND TITLE (Continued)

A-43 Advanced Wastewater Treatment
A-44 Chlorine as a Disinfectant
A-52 Street Runoff
A-54 Rural Treatment Systems
(See also A-1, A-2, A-5, A-7, A-33, A-24)

- ECOLOGICAL EFFECTS

A-24 Irrigation Practices
A-27 Natural Pest Control Agents
A-32 Silviculture Practices
A-33 Biological Pollution
A-38 Soil Sulfur Deficiency
(See also A-1, A-4, A-14, A-31, A-35, A-42)

- RADIATION AND SOUND

A-21 Noise
A-22 Microwave Radiation
A-41 UV Radiation
(See also A-15, A-42, A-50)

- SOCIAL

A-57 Economic Trends
A-58 Crime
A-59 Ascending Power Groups
A-60 Reversal of Core City Population Decline
A-61 Demography
A-62 Medicine Science
A-63 Government
A-64 Transportation
A-65 International

A-1. DISPOSAL OF SECONDARY TREATMENT SLUDGES

With the advent of universal secondary treatment in the United States, there is going to be the increased problem of disposal of the excess secondary sludge both in terms of quantity and toxic contaminants.

Stressors

(1) Heavy metals
(2) Viruses and pathogenic bacteria
(3) Dissolved inorganic salts

Discussion

Many pathogens and viruses pass untouched through sewage treatment plants. With the advent of the mercury scare, many governmental agencies analyzed decayed secondary sludges for heavy metals and found surprisingly high contents of mercury, cadmium, arsenic, etc. Utilization of this secondary sludge as a fertilizer or disposal in a sanitary landfill requires study with respect to toxic metals hazardous micro-organisms and inorganic salts released to the natural environment.

The future addition of phosphorous removal by mineral addition will result in a doubling of the sludge volume at a given treatment plant.

A-2. SLUDGES, LIQUID, AND SOLID RESIDUES FROM POLLUTION CONTROL

Soluble and insoluble organic and inorganic materials are being generated at a rapidly increasing rate as a result of the implementation of pollution control measures. Options for disposal of these residues are being limited by environmental and land use restrictions. Disposal without readmission of hazardous components of these residues to the environment via air, water, soil media constitutes a serious immediate and future problem.

Stressors

(1) Fine particulates in air
(2) Toxic or hazardous organics and inorganics
(3) Contamination of water media.

Discussion

The implementation of pollution control to meet currrent and anticipated environmental legislation with respect to air, water, and land pollution is resulting in large quantities of sludges, liquids, and solid wastes. These wastes contain large quantities of toxic or hazardous substances usually in low concentration. Current disposal options can result in re-admission of these substances to the environment. For example, the disposal of sludges on land used for agricultural purposes can result in the uptake of the heavy metals by plants. Upon being fed to cattle, a route to man's source of food is established. Landfilling can result in contamination of water courses as a result of leachate containing heavy metals and soluble organic constituents. Currently, no disposal method is without some environmental impact.

A-3. IMPACTS FROM FLUE GAS TREATMENT

The environmental consequences of the disposal of acid or alkali wastes from flue-gas scrubbing (chiefly desulfurization) systems have not yet been adequately defined.

Stressors

(1) Alkali wastes
    (a) Calcium Sulfite
    (b) Gypsum

    - (c) Calcium Carbonate
    - (d) Calcium Hydroxide
    - (e) Mangesium Sulfate
    - (f) Calcium and Magnesium Nitrate
- (2) Sulfonic Acid, H_2SO_3
- (3) Metallic Oxides
- (4) Trace Organics

Discussion

Lime, limestone or dolomite scrubbing are among the leading systems which have been examined for power plant flue-gas-desulfurization. The sulfur oxides removed are incorporated in a sludge containing a mixture of the chemicals listed above. Land disposal of these can result in leaching of alkali salts into ground water. If these wastes are dried, dusting is a potential problem.

On scrubbing flue gas with water, an acidic solution containing sulfonic acid is generated. Neutralization of this solution yields a sludge for disposal.

A-4. EFFECTS FROM DREDGING

The dredging of spoil banks, sediments, and stabilized anaerobic lagoon sludges can create immediate adverse effects and initiate long-range chronic ecological upsets.

Stressors

- (1) Trace metals
- (2) Alkalinity and acidity
- (3) Suspended matter
- (4) Dissolved oxygen reduction
- (5) Toxic organometallics.

Discussion

Contact of air or dissolved oxygen with organic substances stirred up by dredging of spoil banks, stabilized sediments, and anaerobic sludges, creates an immediate ecological upset resulting in the release of colloidal clay, humate, and highly charged sulfite trace contaminant complexes. For example, dissolved oxygen can oxidize sulfhydral groups significantly releasing heavy metals, which in turn can be methylated to a toxic form. The quality of the waters in contact with these solids will be significantly deteriorated with respect to dissolved oxygen, redox- potential, alkalinity and acidity, and suspended solids. With further dilution these waters will alter the natural ecosystem through the released toxic metals.

A-5. OIL WELL AND OTHER WASTE BRINES

Salt brines generated from oil well drilling operations and other sources pose an ultimate disposal problem.

Stressors

(1) Dissolved salts
(2) Hydrocarbons in water.

Discussion

Domestic oil drilling as a remedy for U. S. energy needs will increase. Geothermal energy extraction involves bringing large quantities of salt water to the surface. Water desalination on a large scale is another source. Waste brines are also generated in many other industrial activities. Depending upon disposal mode, the brines pumped to the surface can increase the salinity of surface streams or ground water (if deep well injected in the wrong stratum). This is already a problem in producing areas, e.g., Ohio.

Evaporation to dryness (which is costly) is a route, but the resulting salt must be disposed of in a controlled manner.

A-6. COAL CLEANING RESIDUES

Solids rejected from mechanical coal-cleaning processes creates both a solid waste disposal problem and cause water-pollution in the form of acid-mine drainage.

Stressors

(1) Pyritic minerals
(2) Unsightly waste piles
(3) Acidity.

Discussion

Physical removal of pyritic sulfur from coals is the most technologically advanced method of reducing sulfur content of coals. In this method of desulfurization, significant quantities of the minerals, including most of the pyrites, as well as some coal is rejected. This material may constitute from between 5 and 20 percent of the run of mine coal. Disposal of this reject material presents a problem. It does not easily support plant growth, and when left exposed presents a source of acid-mine drainage. If the low-grade coal present in this reject fraction is burned, a significant source of sulfur dioxide is created because of the high sulfur content. Coal cleaning is not only associated with the preparation of some steam coal for shipment to electric utilizies, but is also a part of most coal desulfurization and coal gasification processes.

A-7. WASTE INDUSTRIAL ACIDS

Industry generates large amounts of acid wastes. Disposal is a problem especially when deep well and ocean disposal are restricted by existing legislation.

Stressors

(1) Acids
(2) Heavy metals (Cr, Cd, Zn)
(3) Waste soluble sludges.

Discussion

Industrial processes such as TiO_2 production, chlorination of hydrocarbons, pickling of steel, certain aromatic alkylations, and explosives manufacture generate large amounts of byproduct acids, frequently as aqueous solutions too dilute to be evaporated for acid recovery. In the past, these wastes have been injected into deep wells or dumped at sea. New regulations may halt this practice. Neutralization with lime or limestone creates a sludge ($CaSO_4$) and soluble salts ($MgSO_4$, $CaCl_2$, $MgCl_2$). The soluble salts can contaminate ground and/or surface waters. Toxic heavy metals in comtaminants of pickle liquores, electroplating wastes, etc., are also well-known.

A-8. ACID MINE DRAINAGE

Mine drainage has been a major environmental stressor for the last decade. Increasing demands for energy and natural mineral resources, especially coal, acid mine drainage will remain a significant environmental nuisance.

Stressors

(1) Acidity

(2) Toxic heavy metals such as As, Se, Cd, In, Th, Cu, Zn, Fe, and Mn

(3) Reducing suspended solids (e.g., FeS_2 and $FeSO_4$)

(4) $SO_4^=$ and $S^=$, sulfate and sulfide.

Discussion

Mining wastes have a high content of mineral acids, and these acids alone are a direct environmental hazard. Presently, million of tons of acid mine water drain into the streams of the U. S., damaging approximately thousands of miles of streams yearly. Mine leachates contain toxic heavy metals such as Cd, Mn, As, and Th which have been observed to accumulate in the stream biota or abiotic suspended matter. Chemical or biological conversion to more toxic forms, e.g., organometallics and cycling or accumulation to specific trophic levels are possibilities. Strongly reduced forms of these metals will reduce dissolved oxygen and other oxidized elements. Suspended solids containing FeS_2 and $FeSO_4$ are in a highly reducing state. Sulfate levels of 2000 mg/l in water will progressively weaken or kill cattle.

A-9. FINE PARTICULATES IN AIR

Chemically active and inert fines particulates emitted to the air constitute a potentially serious health hazard due to their retentivity in the human respiratory tract.

Stressors

(1) Asbestos
(2) Glass fibers
(3) Sulfates and nitrates
(4) Heavy metals (Se, Cd, Zn, Hg, Cu, As,
Pb, Ni, As, V, Mn, Cr, etc.)
(5) Organics (POM, benzo[a]pyrene, etc.)

Discussion

The degree of retention of fine particulates in the human respiratory system has been demonstrated to be quite high below about 3 μ, reaching a peak at 1.0 μ. The magnitude of the problem is expected to become more apparent as particulate removal technology is applied to point sources. Few devices are 100 percent efficient so that some escape of particulates at the lower end of the particle size spectrum occurs. The hazard posed by trace toxic materials is fine particulate form is disproportionate to the mass of particulates involved. Furthermore, the hazard exists for both inert and chemically active particles.

Asbestos. Chemically inert, asbestos is recognized not only because of its small size, but because its high length-to-diameter ratio increases its likelihood of being trapped in the lungs. The problem is a particularly acute one in mining and product manufacturing activities (home insulation), but extends to the general public as a result of its use in and erosion from rubber tires.

Fiberglas. Like asbestos, this one is chemically inert, irregular in shape and widely used in materials manufacture and construction (e.g., insulation in homes).

Sulfate. Preliminary results from EPA's Community Health Effects Surveillance System program (CHESS) have indicated that a potential correlation exists in air between SO_x, and fine sulfate particulates and adverse human health effects. The sulfate particulates create health effects at levels an order of two in magnitude lower than SO_2 itself (i.e., 1-10 $\mu g/m^3$). It is possible to speculate that a similar correlation exists between NO_x and fine nitrate particulates. Combustion and automotive sources of this stressor are widespread, but more concentrated in population centers.

Heavy Metals. Control technology applied to particulate emissions from primary and secondary ferrous and nonferrous industry processes is not 100 percent efficient. It is known, e.g., that a substance like selenium will actually become a more concentrated component of the fine particles which elude collection by electrostatic precipitators and mechanical baghouses employed by the lead-zinc ore processing industry. Heavy metals are also emitted as part of coal burning power plant particulates and many become important from the application of catalytic control devices to auto exhaust systems (discussed under a separate problem area).

A-10. TOXIC SUBSTANCES IN RECYCLED ANIMAL WASTE

Recycling of animal wastes, i.e., refeeding back to the animal is considered a possible method or reutilization of this type of waste. However, there is a potential toxic substance build-up in the animal waste, creating a threat to animals, the humans who consume the products, and the ecology in general.

Stressors

(1) Feed additivies (antibiotics, arsenicals, nitrofurans, etc.)
(2) Heavy metals (copper)
(3) Pesticides and larvicides.

Discussion

A sizeable fraction of the solid waste generated in the U. S. is animal feed lot wastes (feces, urine, and others). Because these wastes still contain high percents of nutrients that could be reutilized by animals, closed systems for reprocessing these wastes back to animal feed are being developed. However, toxic substances from feed additives and animal pest control agents find their way into the waste and continual recycling of the wastes through the animal and may build-up these substances to toxic levels within the animal.

Weed additives consist of antibiotics, arsenicals, nitrofurans, heavy metals, etc., which are growth promoters and disease preventors. It has been speculated that certain antibiotics used in feed may cause bacteria in animals to become resistant to the antibiotics. The same bacteria transmitted to man could establish a resistant strain more difficult to control with antibiotics.

Pesticides and larvicides are used in animal feed lots. Contact of these with the wastes are another source of toxic contaminants.

A-11. AUTOMOTIVE EXHAUST

With the removal of lead from gasolines, increasing attention is being focused on other fuel additives such as manganese, and the changes in exhaust composition, e.g., increases in polycylic organic materials, (POM), e.g., benzo(a)pyrene. It is evident that resolution of new problems will be needed in connection with such a major shift in technology in the mid 1970's.

Stressors

(1) Polycyclic organic material (POM) [e.g., benzo(a)pyrene]

(2) New fuel additives, e.g., manganese, xylene, toluene, benzene

(3) Catalytic convertor emissions
(See problem statement A-12).

Discussion

Epidemiological studies indicate that air pollution may play a role in lung cancer induction. Certain organic carcinogens, normally present in polluted air, particularly benzo(a)pyrene, have been shown to increase tumor incidence in experimental animals.

The major emission sources of organic carcinogens, particularly of polycylic organic materials are motor vehicle exhaust, refuse burning, industrial processes, heat-generation sources, such as burning coal, oil, and gas. The removal of lead from gasoline appears to increase the POM emissions from motor vehicle exhaust.

With respect to fuel additives, the several hundred now used is expected to double or triple in number in the next 10 years. Little is known about the health effects of fuel additives and how they alter motor vehicle exhaust compositions. Alkyl amines used as substitutes for lead alkyls can give rise to alkyl nitrosoamines.

Some fuels, to compensate for lead removal, apparently contain a higher quantity of aromatic hydrocarbons such as xylene, benzene or toluene. Consequently, for automobiles (without catalytic converter) the aromatic content in exhausts can be expected to increase significantly. Aromatics have been implicated as cancer causing agents, e.g., benzene and leukenia.

Manganese based additives are high on the list as a lead replacement. The implication of this substitution is not well understood.

A-12. CATALYTIC CONVERTORS FOR AUTOS

The auto industry is poised to equip millions of autos with catalytic exhaust convertors in the mid-1970's. Emissions caused by catalyst failure, poisoning, and manufacture are not well understood.

Stressors

(1) Metallic catalysts (Pt, Pd, Ru, Ni, etc.)
(2) Ammonia
(3) Toxic organics.

Discussions

As catalytic convertors pass from the research phase into the development phase, there is concern for such problems as (1) thermal failure of the monolithic catalyst supports, (2) catalyst's life-even with unleaded gasoline, (3) emissions of trace metals and fine catalyst particles, (4) complete failure and dumping of the contents of convertors onto roadways, and (5) carcinogens from the use of fuel additives not designed for the particular catalyst system employed. Industries manufacturing catalyst and convertors will contribute new pollutants to air, water, and land.

One speculation is that, as catalytic mufflers lose their efficiency, significant levels of ammonia will be emitted in the auto exhaust. Reaction of the ammonia with sulfur oxides or halogens in the atmosphere will create additional visibility (particulate) problems or the ammonia will be oxidized to nitric oxide.

A-13. NONDEGRADED ORGANICS FROM SECONDARY TREATMENT

With the advent of universal secondary waste treatment, an increase in nonbiodegradable organics in the natural environment is expected. The extent to which these are converted to toxic forms or accumulate in bays and reservoirs is unknown.

Stressors

(1) Organometallic complexes
(2) Chlorinated hydrocarbons

(3) Decomposed organics

(4) Trace organics.

Discussion

Relatively inert organics have been shown to complex with trace metals. The stabilized metals are thus solubilized allowing them to be cycled back into biota. Also, these trace organics can be chlorinated to form toxic chlorinated hydrocarbons, decomposed to more toxic organic constituents, reacted biologically to form more toxic organometallics, and accumulated in the lakes, reservoirs, and bays to more hazardous concentrations. Thus, while the emissions of inert trace organics might not have direct effects on the environment, they could develop into hazardous accumulations in nature.

A-14. ELECTRIC POWER GENERATION

Electric power requirements in the U. S. are expected to nearly double in the next 10 years. Waste heat rejections to rivers, lakes, estuaries, and oceans from cooling water discharge and air emissions are a major concern from an environmental effects standpoint.

Stressors

(1) Waste heat

(2) Flue gas scrubbing wastes (See A-3)

(3) Radioactive wastes (See A-50).

Discussion

In 1980 the electric power industry (including nuclear) will use about 44 percent of the total water withdrawal from fresh and saline water sources in the U. S. This will be up from 33 percent in 1965. Consumptive use of this water will be only 1 percent, the rest being returned at an elevated temperature to the environment. While no disasterous effects of thermal discharges have occurred, recent studies have indicated some adverse alterations of aquatic life near some power plants. However, in the future years, as larger power plants become operational, accompanied by multiple units at a single site, environmental management of heated effluents at these sites will become more difficult.

The problems of flue gas scrubbing wastes from fossil fuel plants and radioactive wastes from nuclear plant fuel reprocessing are discussed in problem statements A-3 and A-50, respectively.

A-15. DRINKING WATER TREATMENT

The increased contamination of drinking water is fast becoming a primary concern of the general population. With the growth of industry to meet public material demands, conventional water treatment practices must cope with new trace toxic chemical and biological substances.

Stressors

(1) Industrial organic compounds, e.g., polynuclear aromatic hydrocarbons
(2) Industrial inorganic compounds, e.g., trace metals and fine particulates
(3) Taste and odor from low threshold compounds
(4) Pesticides, herbicides, and fungicides such as chlorinated hydrocarbons, mercurials, arsenic herbicides, etc.
(5) Viruses and pathogenic bacteria
(6) Asbestos, glass fibers
(7) Radioactive substances (tritium, radium, strontium)
(8) Sludge from water treatment.

Discussion

A variety of chemicals both organic and inorganic, e.g., pesticides, herbicides and fungicides, find their way into the air, water, and land environment and eventually into various water supplies. Many of these substances are either relatively nonbiodegradable, such as the polychlorinated biphenyls or are slowly converted to even more toxic substances. Many of the toxic organics cannot be removed from water supplies by conventional treatment methods.

Taste and odor are difficult to control in our drinking water. The major difficulty is that the compounds producing the taste and odor problem, though present in very low concentrations, have extremely low taste and odor thresholds.

Present methods of water treatment do not remove adequately pathogenic bacteria and viruses such as salmonella, hepatitus, and spinal meningitis.

Inorganics include asbestos which has been implicated in intestinal cancer due to ingestion. Asbestos gets into water from such sources as asbestos-containing pipes for water transport, natural rock formations, and industrial waste discharges. Lead, cadmium, and glass fibers are other inorganics where more information is needed.

Disposal of large volumes of sludges from drinking water treatment are part of the overall problem of waste residues from many sources. Toxic components in these sludges need study.

Drinking water rates high as a future problem because (1) it is a direct route to man of toxic substances, (2) it has not received the emphasis in past environmental R&D problems as has other areas, e.g., wastewater treatment, and (3) the recycling of municipal wastewaters is being seriously considered in certain water-short areas.

A-16. DISPOSAL OF WASTE OILS FROM OIL SPILLS AND OTHER SOURCES

Waste oils or constituents from waste oils when emitted to the environment constitute a potential health hazard to man and wildlife.

Stressors

(1) Heavy metals
(2) Organic (oily) compounds
(3) Gaseous materials
(4) Organic acids.

Discussion

Waste oils from industry are generated at an estimated annual rate of 100 million gallons. In addition, 1.8×10^9 gallons are accumulated annually as a result of oil spills. These oils are known to contain quantities of toxic and potentially hazardous substances such as lead, vanadium, chromium, zinc, sulfactants, and organic acids. Use of these oils for dust and weed control, although presently acceptable, could result in underground water and surface water pollution due to leaching of toxic constituents. Landfill disposal can also result in contamination of water supplies. Incineration is questioned because of unsatisfactory particulate and gaseous emissions control.

A-17. BULK SHIPMENT OF LIQUEFIED GASES

The bulk ocean transport of liquefied natural gas (LNG) and other liquefied gases is fast becoming a reality. Extrapolating from past oil tanker spills (Torrey Canyon), it is obvious that a major spill of this type commodity at sea or into a waterway can produce significant environmental hazards.

Stressors

(1) Liquid anhydrous ammonia
(2) Liquid natural gas
(3) Liquid hydrogen
(4) Liquid oxygen

Discussion

Using liquid anhydrous ammonia as an example, three principle environmental hazards arising from a major spill of a liquefied gas can be identified.

Explosion and Fire. This hazard would be an immediate one, although the evidence is that ammonia is a hard gas to ignite. Given time, dilution and dispersion would reduce the fire and explosion hazard to a minimal level.

Atmospheric Pollution. This will undoubtedly be the most important hazard associated with a large spill of ammonia, i.e., immediate high concentrations of NH_3 toxic to humans. Once atmospheric dilution and dispersion have reduced the concentrations to below unsafe levels, the problem is pretty well eliminated so that no long-term atmospheric pollution hazard would persist.

Water Pollution. The major immediate hazard would be ammonia concentrations toxic to marine life. There can be longer range deleterious effect on the aquatic ecosystem.

A-18. BULK SHIPMENT OF LIQUID CHEMICALS AND FUELS

Large scale shipments of liquid chemicals or fuels is known to pose environmental hazards. New commodities for bulk shipment at sea, such as methanol, pose vapor and water contamination threats that require study.

Stressors

(1) Methanol
(2) Other liquid fuels
(3) Petrochemicals (See A-19).

Discussion

"Methyl fuel", largely methyl alcohol, is being actively studied as a boiler fuel. It is less costly to convert natural gas to methyl fuel for transport in conventional tankers than to ship LNG if the source of gas is more than 3500 miles from the point of use. In a spill methanol vapors would be more toxic than gasoline. Completely soluble in water methyl fuel would be toxic to marine organisms. Upon dilution below the toxic level, it would still constitute a BOD burden.

A-19. SPILLED PETROCHEMICALS

Petrochemical products currently being transported via waterways could represent a potential for substantial environmental damage if accidentally or purposely released.

Stressor

(1) Crude oil, gasoline, naphtha, other refined petrochemical products.

Discussion

Barge transport of the above materials on the nation's navigable rivers is increasing at a rapid rate. Along with the increase in traffic, the physical size of the barges and the size of the tows are increasing leading to decreased manuverability, a fact with enhances the potential for collisions, grounding, etc. Similar results will occur from the increase in petroleum product shipments in supertankers and normal size tankers. Operational spills, i.e., due to equipment failures, errors will increase. The introduction of these wastes into sensitive marine, estuarine, and freshwater environments can have serious detrimental effects upon aquatic biota, not to mention explosion and fire hazards.

A-20. CRANKCASE OIL RECYCLING/DISPOSAL

Recycling of crankcase oil will generate heavy metal wastes.

Stressors

(1) Heavy metals (Zn, Pb, etc.)
(2) Acidic sludge

Discussion

Some proposed processes for reprocessing of used crankcase oil for automotive use generate a waste fraction containing heavy metal salts and acid sludges. If the used oil is disposed of by incineration, the metals end up in the ash which will need disposed. Particulate emissions to the air from incineration are a distinct possibility.

A-21. NOISE

Uncontrolled and inadequately controlled noise is becoming a growing nuisance. Some evidence of health impairment exists. Identified physiological and psychological effects include speech interference, hearing impairment, sleep disturbance, and stress reactions.

Stressor

(1) Noise.

Discussion

The noise level in major cities from cars, buses, trucks, construction, etc., is, if anything, increasing. New mass transit systems may add to the problem.

Factory noise, while now under OSHA standards, is a problem in many industries. A trend towards even larger machines, especially agricultural tractors, earth movers, cranes, planes, etc., continues.

Home appliances are particularly important sources of noise not because of the decibel level (although high fidelity equipment is loud) but because the noises are persistent. Studies suggest that prolonged exposure may contribute to impairment of hearing.

Differences of 1000 in the exposure standards between various countries emphasize the need for research to provide necessary data to either accept to reject the nonthermal response concepts. Further information is also needed on cumulative effects of repeated small doses, delayed effects, damage which can be observed only with groups of persons and may not occur until a certain latent period has elapsed, and genetic effects.

A-22. MICROWAVE RADIATION

In recent years the number of sources of microwave radiation has grown significantly--military and civil radar, TV transmitters, microwave ovens, etc.,--will continue to grow in the future. Insufficient knowledge exists with respect to human effects, especially nonthermal effects at low radiation levels.

Stressors

(1) Microwave energy

Discussion

Microwave radiation is emitted from a variety of electronic devices including diathermy units, ovens, industrial processing equipment, television transmitters, radio transmitters, and radar units. Effects may be basically classified into predominantly thermal effects where the transfer of energy to the system increases its energy only in a random manner, and predominantly nonthermal effects characterize by specificity of the affected target. Thermal effects occur largely in the skin, testicles, and eyes with cataracis being the most common manifestation. Exposure at very high levels is fatal due to myocardial necrosin and hemorrhages. There is disagreement concerning nonthermal effects which may be produced at low power densities and may affect the nervous system, auditory responses, cardiovascular system and other behavioral patterns. There is a lack of information on cumulative effects of repeated small doses, delayed and genetic effects. Exposures involve the general public as well as occupational groups in industry, medical areas, commerce, educational, and research institutions.

A-23. INORGANIC TOXIC CONTAMINANTS

Widespread and increasing concentrations in the environment of trace inorganic contaminants especially heavy metals from domestic, industrial, and other wastes has only recently been fully recognized. The need for control over point and area sources will be of major interest in the coming decade.

Stressors

(1) Arsenic, As
(2) Cadmium, Cd
(3) Chromium, Cr
(4) Cyanide, CN
(5) Mercury, Hg
(6) Selenium, Se
(7) Copper, Cu
(8) Zinc, Zn.

Discussion

The accumulation of toxic inorganic contaminants in the natural aqueous environment has occurred due to population growth and its demand on industry for materials. There is a need to know the hazard levels for each component and its means of transport through our environment. Recent incidents involving mercury has shown how near to their hazardous limits some of these contaminants are in the environment. There must be a cognizant model for the hydrodynamic, abiotic physical-chemical, and biotic transport of these hazardous or probable hazardous trace contaminants so that a reasonable and safe limit can be obtained. This is an all media problem and widespread in the U.S.

A-24. IRRIGATION PRACTICES

Irrigation of arid lands leads to contamination of water supplies, possible transfer of hazardous contaminants to the environment, a degradation of the fertility of irrigated soils, and a deterioration of downstream rivers and estuaries.

Stressors

(1) Salinity
(2) Dissolved oxygen reduction
(3) Toxic heavy metals
(4) Temperature elevation
(5) Pesticides.

Discussion

The direct stress caused by irrigation is the continuant rise of the saline content of irrigation waters. The average salinity for the lower Colorado River and the Hoover Dam is now between 750 to 850 mg/l. Natural, irrigation, and miscellaneous saline sources have been found to contribute

48 percent, 36 percent, and 16 percent, respectively, to the irrigation salinity in the reservoir. Irrigation return flow brings with it nutrients, pesticides, heavy metals, turbidity, and refractory organics, all of which have an adverse effect on water quality.

To supply irrigation needs, the storage of large quantities of waters becomes necessary and this storage is done by damming rivers which flow through arid regions. The augmentation of these rivers has a great impact on the downstream river environment. Since these arid ecosystems are delicately balanced, augmented flow can lead to the destruction in time of productive lands. Low flow will reduce the waste assimilative capacity, and raise the temperature of the downstream river.

As the saline content of irrigation water rises, crops with a low salt tolerance become affected.

A-25. METALLIC MACHINING SLUDGES

The disposal of industrial machining sludges, where metal recovery is uneconomic, is a problem in certain industries especially those transitioning to electrochemical machining.

Stressors

(1) Toxic inorganics
(2) Toxic organics
(3) Salinity.

Discussion

Electrochemical machining use is increasing rapidly. A high saline solution is used resulting in sludges with saline contamination. The metal materials will be much more highly dispersed as finer particles in the machining sludge. Materials used in cutting tools are changing, e.g., boron containing materials are replacing the older tungsten-carbide for example. Many alloys contain vanadium, chromium, etc., and other

toxic inorganics. Organic additives included in cutting lubricants and coolants may be toxic requiring additional care in disposal of separated liquids and sludges.

A-26. CHLORINATED HYDROCARBONS, PESTICIDES, HERBICIDES AND FUNGICIDES

Because of their persistence and toxicity chlorinated hydrocarbon residues continue to be discovered in air, water, and land media. Similar situations have been observed with arsenic herbicides, organic mercurial fungicides and related substances.

Stressors

(1) DDT
(2) PCB (polychlorinated biphenyls)
(3) HCB (hexachlorobenzene)
(4) Dioxin
(5) Unknown trace organics (chlorinated or not)
(6) Mercurial and arsenical compounds.

Discussion

In the 1960's DDT was implicated as hazardous to the environment due to its persistence and toxicity. Stringent measures were undertaken to contain this accumulative poison. In the early 1970's PCB and degraded DDT were found to have far reaching effect on the environment e.g., a reduction of the sea lion populations due to premature births. More recently HCB, which has been used as a cattle growth simulator, has been found to cause serious skin eruptions, liver degeneration, or fatal illness in a couple of days for laboratory animals. It has been outlawed for use by the FDA. A Swedish ornithologist has found a direct correlation between the near extinction of many birds of prey and the utilization of the fungicide methylmercury chloride from 1940 to 1964. A vigorous study on the use of arsenic containing herbicides has resulted in the banning of their use by EPA. Dioxin, a contaminant of certain herbicide formulations has also been implicated as a highly toxic substance. The problem of buildup in toxic pesticides, herbicides, and fungicides will persist as long as there is a demand for such agents in our natural environment by man.

A-27. NATURAL PEST CONTROL AGENTS

The banning of DDT and the general concern about pesticides, herbicides and insecticides is resulting in pest control programs based on natural agents combined with synthetic chemical ones. The consequences could be significant.

Stressors

(1) Genetic effects
(2) Species irradication

Discussion

The development of sex attractants, hormones, bacteria and viruses for controlling plant and insect infestations is underway and intergrated chemical/biological pest control programs are a reality. While there is little evidence to support the notion, it appears desireable at this relatively early stage to examine the consequences of such methods, especially the ecological imbalances that could result, e.g., eradication of desirable populations or adverse genetic changes in animals.

A-28. FLUORINATED HYDROCARBONS

Increased exposure of humans to concentrations of fluorinated hydrocarbons in the environment can be expected. Little is known about the health effects. Fluoride emissions from manufacturing are well known.

Stressors

(1) Freons
(2) Fluorine
(3) Fluorocarbons.

Discussion

Air conditioning of autos, homes, offices, plants, apartments, and high-rise buildings is growing even in mild climate areas. Leakage of freons in these closed systems may result in higher than normal human exposure levels. Increased use of freon powered aerosol cans adds to the concentration of these substances in closed environments. At the' same time manufacture of these freons and products containing them may result in emissions.

Fluoride emissions from phosphate mining and conversion to fertilizers and acids, clay and glass products manufacture, and iron and steel manufacture are known which contribute significant environmental burdens over wide areas of the U.S. to all media.

A-29. CARCINOGENS

Emissions of carcinogens are not well defined as yet. However, one apparent industrial source is the manufacture of synthetic organic dyes and pigments, resins for water treatment, and many consumer products. This and other sources raise the possibility of wider exposure of man to carcinogenic chemicals.

Stressors

(1) Industrial chemicals (e.g., those from synthetic dye manufacture:
- (a) Benzidine
- (b) Beta-naphthylamine
- (c) Bis-chloromethyl ether
- (d) Dichlorobenzidine
- (e) Beta-propiolactone

(2) Combustion and agricultural sources
- (a) POM's
- (b) Nitrates-nitrites-nitrosoamines

Discussion

The organic dye industry is a convenient example of a source of carcinogens. Benzidine and beta-napthylamine are starting materials for many synthetic dyes. Sales of benzidine and benzidine dyes total approximately $14 million a year. Dichlorobenzidine is used to prepare pigment colors. These pigments, in turn, are widely used for inks in newspapers and magazines.

Bischloromethyl ether is an unavoidable by-product in the production of chloromethyl ether, in turn used to make resins for producing high quality deionized water. The water is used for electrical generation and electronics manufacture. Bischloromethyl ether can form spontaneously in ordinary humid air whenever formaldehyde and HCL come together. The latter two chemicals are used in the treatment of fabrics, manufacture of flame proofing agents and manufacture of insecticides, herbicides, dispersing agents, and water repellents.

Beta-propiolactone is used to sterilize tissue grafts and vaccines and in producing acrylates.

Beta-naphthylamine has been reported in coal-tar products, cigarette smoke condensate, and flue gases of industrial boilers.

From combustion sources come carcinogenic polycylic organic materials (discussed elsewhere) and oxides of nitrogen. The latter can be converted to nitrates by the action of photochemical smog. Nitrates can be converted into intrites by soil bacteria or intestinal flora. Reaction of secondary amines with nitrites to form nitrosamines which are highly carcinogenic can cause serious health effects. Besides combustion sources, agricultural practices (fertilizer and feedlot runoff) contribute nitrates to environment.

A-30. INCINERATION OF NEW MATERIALS

Incineration of new materials will introduce potentially hazardous materials into air, water, and land media.

Stressors

(1) Antimony oxide/chloride
(2) Hydrogen chloride
(3) Hydrogen bromide
(4) Polynuclear aromatics
(5) Sulfur compounds
(6) Fluorocarbons
(7) Cyanides from nitrile-gassed plastics.

Discussion

The need for solid waste disposal is likely to lead to more incineration than in the past [in lieu of landfill]. New materials of construction, flameproof textiles and carpets, and maybe even plastic paper will introduce new problems on top of those now encountered with plastic packaging, old tires, and huge volumes of newsprint.

Antimony Oxide/Chloride. To make plastic materials of construction nonflammable, antimony oxide is introduced as a filler, with some source of chloride, which may be the plastic itself. On burning the material evolves antimony chloride fumes which can hydrolyze to antimony oxide and hydrochloric acid. Incineration of those materials will give rise either to antimony chloride in the flue gases or antimony oxide in the ash. The hazard due to the antimony from this source needs to be investigated.

Hydrogen Chloride and Bromide. In addition to hydrolysis of antimony chloride, the incineration of polyvinyl chloride, neoprene, Saran wrap, and chlorinated paint solvents will generate hydrogen chloride, which will leave in the flue gas. Hydrogen chloride is very corrosive to metals and basic refractories and kills vegetation. Breathing of the substance causes damage to lung and other tissues of the respiratory system. (Certain chlorine containing plastics, such as PVC, must be incinerated at elevated temperatures to get complete combustion. At lower temperatures, they melt and coat the grates, causing a mechanical problem.)

Some paint and plastics contain organic bromine compounds instead of chlorine compounds.

Polynuclear Aromatics. When organic aromatic polymers such as polystyrene, styrene butadiene rubber, or ABS plastics are burned, solid particles in the smoke are likely to contain polynuclear aromatics, some of which, such as pyrene and dibenzanthracene, are known carcinogens. Thus tires, some plastic packaging and paper, and some plastic building material are a potential hazard. Proper removal of particulate will reduce the problem to that of a solid waste problem. (Roofing tar heated to the smoking point produces a similar hazard, which is largely uncontrolled.)

Sulfur Compounds. Complete incineration of rubber tires will convert the sulfur used for vulcanizing to SO_2. Incomplete combustion produces mercaptans, thioaldehydes and ketones and other foul-smelling materials.

Fluorocarbons. The high temperature incineration of Teflon and other polyfluorocarbons produces smaller fluorinated organics. Their fate in the flue gas is unknown. Hydrogen fluoride is also formed, which is corrosive and toxic.

Nitrile Plastics. Nitrile plastic bottles being test marketed by several soft drink firms have been cited as giving off cyanide upon incineration. The potential market is 50 billion bottles per year. Furthermore, such bottles are not readily biodegradable.

A-31. OIL SHALE POLLUTION

Leaching of soluble salts and metals from spent oil shale.

Stressors

(1) Soluble salts
(2) Vanadium
(3) Shale residues (large volumes).

Discussion

Soluble salts of sodium and other elements are frequently present in the oil shale. Spent oil shale expands 50 percent in volume during processing and thus all of the spent rock cannot be put back into the mine. Runoff from the spent shale piles will leach these salts and transport them to nearby watercourses. Since the oil shale deposits are in the upper Colorado River Basin, the salts will be added to a river already having salt problems at its lower end.

Vanadium is a component of many shales. If not recovered during shale processing its susceptability to leaching may be enhanced, depending on the shale process employed.

A-32. SILVICULTURE PRACTICES

The forests of the United States have outputs other than wood, and when manipulated can have unexpected and often significant detrimental impacts upon other environmental components.

Stressors

(1) Erosion and sedimentation
(2) Slash disposal
(3) Storage and movement of physical and chemical materials
(4) Burning as a management technique

Discussion

The pollution resulting from silvicultural practices is of a complex non-point source nature being the result of activities taking place over hundreds or even millions of acres. Furthermore, there are no "black box" devices for use in controlling silvicultural-based problems. The best control measures are generally preventive measures manifested in the planning, scheduling, and actual conduct of the various silvicultural activities. The highly diverse conditions of topography, climate, soil, etc., which characterize the forested regions of the U. S. further complicate the control of silvicultural pollution by limiting the forest management and timber harvesting options available to the forester.

(1) Erosion and Sedimentation. These are naturally occurring phenomena in all forest ecosystems, disturbed or undisturbed. However, such operations as road construction and maintenance, and certain logging techniques can significantly accelerate the processes and lead to surface and/or mass erosion, and downstream sediment damage. For instance, studies have shown that logging operations alone increased sediment production by a factor of about 0.6 over the natural sedimentation rate. When the road construction and use associated with the logging operation was considered, sediment production increased about 750 times over the natural rate for a six-year period following road construction. The practice of clear cutting of forest has been implicated as contributing to nutrient runoff.

(2) Slash Disposal. Presently, logging slash is most commonly disposed of by either mechanical means or fire. Both of these techniques have environmental and/or technological constraints which limit their use in the treatment of logging slash. For instance, extremes of topographic conditions can limit the use of mechanical devices. Furthermore, heavy equipment can result in undesirable soil compaction and a reduction in water infiltration

rates. On the other hand, burning techniques (broadcast burning, pile burning, etc.) can lead to air pollution problems. As an example, the energy release rate from most slash fires is too small to provide a plume rise sufficient to minimize air pollution problems.

(3) Storage and Movement of Physical and Chemical Materials. The storage, movement, and ultimate fate of physical and chemical materials including excessive amounts of naturally occurring organic matter, pesticides applied for insect and disease control, chemical fertilizers, fire retardants, etc., are complex processes in the forest ecosystem. Their indiscriminate use can lead to unanticipated, far-reaching effects both within and outside the forest in which they were applied.

(4) Burning as a Management Technique. This management technique has been a common silvicultural practice for many years. It is used not only for slash disposal, as mentioned above, but also as a prescribed method for reducing the accumulation of forest residues and hence, the occurrence of disasterous wildfires. Prescribed burning is also an accepted method of site preparation in reforestation efforts. The air pollution problems resulting from these prescribed fires are much the same as those resulting from slash burning.

A-33. BIOLOGICAL POLLUTION

In the 1960s, a classic example of biological pollution was observed in the Great Lakes with the accidental introduction of the lamprey which in effect destroyed a whole fishing industry. With increased technology and travel throughout the world, the possibility of similar happenings is becoming more and more of a possibility.

Stressors

(1) Viruses

(2) Bacteria

(3) Larger organisms.

Discussion

With the advent increased technology and travel, the possibilities of the pollution of our natural ecosystems by foreign organisms is becoming a reality. Recently, this type of pollution has occurred in the Great Lakes with the lamprey, in Australia with the mongoose, and in the United States with near extinction of the primary preditors causing high quantities of deer and rabbits (which cause our farmers a great deal of trouble).

A-34. SPRAY IRRIGATION PATHOGENS

Spray irrigation of municipal waste treatment plant effluents.

Stressor

Human pathogens.

Discussion

Municipal wastewater creates serious pollution problems when discharged directly into surface water. Diversion of wastewater to the land should help to eliminate many of these problems and in some instances might even provide secondary benefits such as increased recharge of groundwater reservoirs, increased growth of vegetation, and amelioration of barren unproductive land. The land disposal of these wastes through such application methods as spray irrigation while increasing in popularity can impose potentially adverse environmental effects. Of most concern is airborne transmission of human pathogens contained in the mist and/or drift associated with spray application. Generally this drift would not be noticeable at great distances from the application site. However, insects, animals, etc., could come into contact with the contaminated drift deposited on the surrounding land area. Furthermore, since these pathogens can survive up to periods of several weeks depending upon existing conditions, the potential for disease transmission exists.

A-35. PIPELINE CONSTRUCTION

Environmental effects of pipeline construction (canaling) and operation in coastal marshes and estuaries.

Stressors

(1) Turbidity
(2) Release of toxic sediments
(3) Barriers to nutrient flushing
(4) Barriers to estuarine organisms
(5) Changes in tidal flow patterns
(6) Canal erosion
(7) Marsh buggy operation
(8) Leaks and spills.

Discussion

In order to meet our nation's energy needs, the President has called for tripling the development of oil and gas leases in our offshore waters. Offshore superport developments and new refining needs will call for hundreds of thousands of new miles of pipeline in the near future. When coastal areas are concerned, i.e., particularly our Gulf and South Atlantic shores, frequently such construction requires rights-of-way through coastal marshes or estuaries. At present, construction practices in such areas call for the excavation by floatation dredge of a canal approximately 40 to 50 feet in width with soil placement to either side to form a levee. Depending upon the quantity and stability of the soil, a levee may be 3 to 5 feet high with a base width of 50 to 85 feet. The canal allows access to a "lay barge" to place the pipeline in the bottom of the canal. Backfilling of the canal is seldom practical or possible. The environmental and ecological effects are extensive as the stressors indicate. Their impacts have been well described in a recent study [McGinnis, J. T., et al., "Environmental Aspects of Gas Pipeline Operations in Louisiana Coastal Marshes", Report to Offshore Pipeline Committee by Battelle's Columbus Laboratories (December, 1972)].

A-36. DEICING OF ROADWAYS

The ever-increasing use of deicing agents for removal of ice and snow from U.S. highways and streets is causing a growing concern over the environmental effects resulting from these practices.

Stressor

(1) Road deicing salt
(2) Chromates
(3) Cyanides
(4) Phosphates

Discussion

Road salts are usually applied at rates of 400 to 1,200 pounds of salt per mile of highway per application. Over the winter season, many roads and streets may receive more than 20 tons of deicers per lane mile. Studies indicate that highway salts can cause injury and damage across a wide environmental spectrum. Furthermore, it is believed that many of these effects, although not yet evident in certain areas of the country, may well appear in the near future. Effects of highway deicing appear most significant in causing contamination and damage of groundwaters, public water supplies, roadside wells, farm supply ponds, and roadside soils, vegetation and trees. Deicers also contribute to deterioration of highway structures and pavements, and to accelerated corrosion of vehicles.

The special additives found in most road deicers cause considerable concern because of their latent toxic properties and other potential side effects. Significantly, little is known as to their fate and disposition, and effects upon the environment. The complex cyanides used as anti-caking agents and the chromate compounds used as corrosion inhibitors have been found in public water supplies, groundwaters, and in storm and combined sewer flows. Unusually small amounts of cyanide and chromium are sufficient to cause rejection of public water supplies and cause death of fish and associated aquatic organisms. The phosphate additives also used for corrosion control may contribute significantly to nutrient enrichment in lakes, ponds, and streams leading to algal blooms and noxious conditions.

In addition, materials storage sites are a frequent source of salt pollution to ground and surface waters.

A-37. NEW LANDFILL TECHNOLOGY

The solid wastes deposited in sanitary landfills are subjected to chemical and biological decomposition to produce certain gaseous products and liquid leachates some of which can be potentially hazardous.

Stressors

(1) Methane
(2) Carbon dioxide
(3) Toxic leachates
(4) Disease carrying vectors (flies, fleas, mosquitos, rodents, etc.)

Discussion

Land disposal of municipal, industrial, and pollution control wastes is certain to increase. Techniques are still developing for this purpose, e.g., shredding and baling of municipal refuse, the use of liners to prevent subsurface leaching, the use of daily temporary covers (organic coatings) to reduce vector access, etc. Insufficient information exists with respect to long-term leachate generation, runoff, etc. The disposal of industrial residues (e.g., oil wastes, machining sludges, coolants, etc.) in municipal landfills requires more definition with respect to effects.

In some instances, methane gas has moved from landfills and accumulated in explosive concentrations in sewers and nearby buildings. Also, gases from landfills have killed nearby vegetation, presumably by excluding oxygen from the root zone. Carbon dioxide movement has resulted in corrosion and chemical reaction in structural systems, and quality changes in groundwaters.

A-38. SOIL SULFUR DEFICIENCY

Sulfur deficiency in certain agricultural areas will occur as a consequence of SO_x control measures.

Stressor

(1) Sulfur deficiency

Discussion

Sulfur is one of the many micro-nutrients required for plant growth. As a micro-nutrient, it is required in only very small concentrations and, therefore, could be toxic at appreciable concentration levels. As many agricultural areas suffer from sulfur deficiency, a reduction in the use of high-sulfur coal on the application of emissions controls in these areas could further exaggerate this deficiency.

A-39. SOLVENTS FROM COATING AND DYEING TECHNOLOGY

Various industrial coating processes generate solvents which contribute to air pollution.

Stressor

(1) Volatile organic solvents

Discussion

The contribution of solvents from industrial printing, painting, and coating have been recognized and regulation in some areas has been instituted (Rule 66 in Los Angeles, Rule 3 in the San Francisco Bay area). Fast drying inks for printing that use solvent will create the same problem as solvent based paints. This will tend to be a "big city" problem.

The trend to solvent dyeing of textiles to avoid disposal problems associated with aqueous dye systems may create problems in new areas of the country, particularly the Southeast.

A-40. SPARK SOURCES

Emissions of ozone and nitrogen oxides occur when a spark or corona discharge through air occurs.

Stressors

(1) Ozone
(2) Oxides of nitrogen

Discussion

Ozone and NO_x are among the culprits in the smog problem. In addition to production in photochemical reactions, they are generated by electric discharges from very high voltage AC powerlines, sparks from electric motors, Xerox machines, etc. If electric automobiles become abundant, the sparks from motors may produce a measurable effect. Very high voltage AC lines are already being built and local effects on vegetation have been alleged by environmentalists.

A-41. UV RADIATION

The effects of solar radiation has been the main input for both natural thermal pollution and photochemical smog, but with the increased input of metals, fine particulates, and nonbiodegradable organics into a homogenous mixture, the effects of short wave solar radiation can be magnified.

Stressors

(1) UV radiation
(2) Fine particulates
(3) Trace nonbiodegradable organics
(4) Heavy metals

Discussion

It is a known fact that solar energy has been a major contributor to photochemical smog and thermal pollution. Because short-wave radiation increases the energy input for reaction (photochemistry), this radiation can result in unstable reactions between heavy metals, nondiodegradable organics, and fine particulates creating new hazardous, toxic, and nonbiodegradable compounds.

Duirng the debate on the SST, it was pointed out that unburned hydrocarbons at high altitude in contact with the ozone at that level and intense UV irradiation would react rapidly. Ozone depletion could allow UV to reach lower altitudes with effects on weather. The issue has never been completely resolved, although plans for the SST were shelved.

A-42. GEOTHERMAL POWER

Of the potential new energy sources, geothermal power is said to be the most readily accessible with current technology. The environmental impacts of this source have yet to be studied.

Stressors

(1) Salt brines
(2) Thermal effluents
(3) Air emissions (H_2S)
(4) Radioactive materials Pb^{210} and Ra^{222}
(5) Heavy metals (Hg, As, Se, Pb, etc.)

Discussion

Geothermal power has been touted as a possible pollution free power source. However, in tapping the earth's inner core, the emission of hazardous gaseous vapors and particulates is possible. These include hydrogen sulfide, radioactive vapors of Pb^{210} and Ra^{222}, corrosive silicates and carbonates, and heavy metal containing water such as Hg, As, Se, and Pb. The deep groundwaters emitted from these ecological tappings have a far higher total dissolved solids, but otherwise, they are similar in quality to other saline groundwaters. Thus, they could contribute to a deterioration of soil productivity.

The above discussed parameters all will have to be investigated fully for their total environmental impact before this form of power is ever utilized.

A-43. ADVANCED WASTE WATER TREATMENT

Improved and new secondary treatment methods, and developing tertiary treatment schemes, should be examined for their environmental impacts. Larger quantities of sludges for disposal, the use of new coagulants, flocculants, etc., and the continuing problem of virus removal are future problems.

Stressors

(1) Increased sludge volumes (see A-1)
(2) Coagulants, flocculants (e.g., polyelectrolytes)
(3) Pathogens
(4) Inorganic carbon

Discussion

The advent of physical-chemical, ozonation, pure oxygen, sonic, and other wastewater treatment shcemes will introduce new problems. The doubled (or better) quantities of sludge for disposal in the case of phosphorus removal was noted in problem A-1. The introduction of new coagulants, flocculants and treatment chemicals should be examined with respect to their degradability, potentially toxic degradation products, etc.

Virus and pathogen removal capabilities of new technology should be examined. Ozonation will disinfect viruses; but the power costs are high, and ozonation does not leave any residual disinfectant to combat pathogenic bacteria which might leach into water supplies. Chlorination inhibits virus activity but the dosage has to be increased ten fold, introducing the possibility of forming toxic chlorinated organics (see A-44). Heat treatment is effective, but the cost is also high and there would not be any residual disinfectant.

Also with the development of efficient biological waste treatment systems, most of the organics will then be converted almost completely to carbon dioxide, and inorganic carbon at high concentrations could itself become a serious pollutant. In the early 1970's inorganic carbon was found to be the limiting nutrient for some specific situations. The emission of high concentrations of inorganic carbon will adjust the pH of the given water system to pH of 8.3, pH > 8.3, and pH around 6 depending on the spcies of the inorganic carbon. High concentrations of carbonate or inorganic carbon will change the form and solubility of most common or toxic metals found in water.

A-44. CHLORINE AS A DISINFECTANT

The best approach for municipal treatment plant effluents disinfection has yet to be determined to compensate for the practice of chlorination and its attendant problem of chlorinated hydrocarbon formation.

Stressors

(1) Chlorinated hydrocarbons (e.g., chloramine)
(2) Viruses
(3) Pathogens

Discussion

The problems of chlorination are basically twofold: (1) the chlorine as now added does not attack viruses or many other pathogens, and (2) there is evidence that effluents of secondary treatment contain nondegradable organics which can be chlorinated to form toxic chlorinated hydrocarbons, e.g., chloramine is formed from the reaction of chlorine with ammonia. Even with these two drawbacks, chlorine and chloramines do kill most microbes and do leave a residue to insure some safety beyond the treatment plant boundaries, i.e., in the stream or water supply system. In European and U.S. investigations, ozonation has been observed to inhibit microbiological activity and does attack viruses; however, ozonation has not been found economical due to the high power costs and no residual ozone remains as a safety measure. Use of SO_2 or O_2 has been investigated as possible alternatives, but with present technology, neither process shows any possibilities for utilization. Meanwhile the hazards of chlorinated hydrocarbons remain.

A-45. URBAN PESTICIDE USE

Contamination of urban air, water and land environments occurs through home application of pesticides, herbicides, and insecticides. Disposal of residues is uncontrolled.

Stressors

(1) Chlorinated hydrocarbons
(2) Organophosphates

Discussion

The application, by home gardeners of pesticides, herbicides, and insecticides results in either direct inhalation of the toxic compounds employed or drifting of them onto adjacent property. Disposal of residual materials and containers is unregulated and may be (1) into garbage cans, (2) storm sewer, (3) sanitary sewer, (4) vacant lot, or (5) nearby dump. The number of different toxic compounds is large comprising primarily chlorinated hydrocarbons (chlordane, PCB's, organophosphates, methyl parathion, etc.). The existance of significant quantities of such substances has been proven in a recent study by EPA of street runoff contaminants .

A-46. CROP DUSTING AND SPRAYING

During the process of pesticide application by crop dusting or spraying a significant amount of pesticides drift away with the wind. Also a sizable fraction is lost by evaporation from the field after application. Large quantities of residues and contaminated containers are frequently inadequately disposed of.

Stressors

(1) Toxic aerosols and dusts
(2) Pesticide, herbicide, insecticide residues
(3) Contaminated containers

Discussion

Though pesticide spraying may be localized, the problems created by wind drift and evaporation may extend to many areas. Nearby urban areas result in an inhalation hazard to the population. Contamination of water supplies from runoff and rainfall is possible.

Large numbers of containers with residues require disposal. Landfilling or simply burying in a hole somewhere are common routes for this purpose. A survey of EPA regions as part of the National Disposal Sites for Hazardous Wastes revealed this as a problem common to many areas of the U. S.

A-47. SULFUR DUSTS

Flue gas desulfurization, sour-gas treatment, coal gasification, and refining of high sulfur crude oils may give rise to stocks of elemental sulfur that may create a dust problem.

Stressor

(1) Sulfur dust
(2) Acidity from H_2SO_4

Discussion

Sulfur removal techniques that give rise to elemental sulfur may increase in importance. Large piles of unsalable sulfur may accumulate at widely scattered points. Dust from operations, especially loading and unloading, may create dust problems. (In Vancouver, B.C., sulfur dust problems became so bad recently that loading of powdered sulfur onto ships was forbidden.) The dust is not particularly toxic but can cause the same respiratory problems any dust does. On standing in contact with soil and moisture, bacterial action generates sulfuric acid that changes the pH of the soil.

A-48. UNDERGROUND MINING

There is growing recognition of water and air pollution problems associated with underground mining and mineral processing.

Stressors

(1) Land subsidence
(2) Physical and chemical pollutants-acid mine drainage
(3) Mining radioactive ores.

Discussion

It has been estimated that unless adequate preventive measures are taken about 2-1/2 million acres of underground mined land will subside between now and the year 2000.

Physical and chemical pollutants drain from these underground mines, especially the bituminous coal mines, polluting lakes and rivers. Approximately 9000 miles of streams and 22,000 acres of lakes are said to be so polluted. Most of these are from the mining and processing of bituminous coal, and with the present and future energy demand the situation will get worse.

Water pollution from the mining of radioactive ores can result in leaching of radium 226 and thorium 230 into nearby watercourses.

A-49. COAL GASIFICATION

With the current oil and natural gas shortages, coal and shale resources as fossil fuel sources is becoming attractive. Coal gasification is being considered as a source of methane. The input of possibly unique pollutants into the environment must be considered at this early stage.

Stressors

(1) Gaseous SO_2 or aqueous H_2SO_3
(2) Methane
(3) H_2S
(4) Toxic organics such as oils, tars, and phenols
(5) Heavy metals

Discussion

Plants to produce gas from coal will be built to augment the country's gas needs. Minimizing pollution from coal gasification plants should be an objective of current development efforts. As currently conceived, removal of air pollutants (fine particulates, sulfur, and organics such as oils, tars, and phenols) by scrubbing will translate the problem to one of possible water pollution. The impact of this must be assessed. Other residues from the process will be aqueous thermal discharges and coal ash.

A-50. RADIOACTIVE WASTES

The ultimate disposal needs for high level (heat producing) and low level radioactive wastes will increase significantly in the next decade.

Stressors

(1) Long half life radioactive elements (Ra, U, Pu, Ce, Co, etc.)
(2) Tritium and Krypton-85

Discussion

The development of the nuclear power industry is underway such that increasing quantities of radioactive wastes requiring disposal can be expected. The bulk of these wastes are generated in mining, conversion, fuel fabrication, and fuel reprocessing.

Ultimate disposal of high level radioactive wastes has been investigated for the past decade. Promising processes include (1) solidification, (2) the ORNL pot calcination process, (3) the Hanford spray-calcination process, and (4) the Brookhaven National Laboratory phosphate glass-fixation. Disposal in salt deposits is being considered, but there are still questions to be solved such as the means of transferring the wastes to the disposal sites and the numbers of salt deposits needed when there are 100 times as many plants.

Low level wastes have been removed from the water using (1) a scavenger precipitation ion-exchange process, and (2) a foam separation process. Just what should be done with the precipitated sludge, ion-exchange regenerate, and the separated foam has not been determined.

A-51. PLANT AND ANIMAL GROWTH PROMOTERS

Additives to soil and animal feeds for the purpose of stimulating protein (food) production are growing in usage. Inadequate information exists with respect to environmental consequences of these substances.

Stressors

(1) Diethylstilbestrol

(2) Toxic organics

Discussion

Widespread adoption of additives by the agricultural community could lead to new difficult to control nonpoint source pollution. Diethyl stilbestrol is an example. Another known substance (properitary) is a highly toxic herbicide, which when applied in low concentration to plant roots actually benefits plant protein growth.

A-52. STREET RUNOFF

Runoff from street surfaces has recently been shown to be similar in many respects to sanitary sewage. Pesticides, PCB's, and heavy metals (Zn, Pb) were significant contaminants along with BOD, nitrates and phosphates. As an area source control is difficult. More study is therefore needed of this problem.

A-53. AEROALLERGENS

Respiratory ailments from aeroallergens are common. There are both natural (ragweed) and man-made (construction activities) sources of these agents. Control is a difficult proposition at best. Some solutions like killing ragweed with herbicides have build-in environmental problems.

A-54. RURAL TREATMENT SYSTEMS

Many rural communities lack sewer systems and have raw sewage and septic tank drainage runoff problems. The financing costs of adequate systems exceed the ability of the few residents to pay. Economical package plant systems are needed.

A-55. HOUSEHOLD PRODUCTS

There are many products used at home which contain toxic components, e.g., hexachlorophene in soaps, talc in baby powders, waxes, cleansers, solvents, drugs, paints, adhesives, pesticides, fertilizers, and gasoline. Consumer practice in disposing of residues and containers include: flushing in the commode, deposit on nearby lots, in garbage cans, down storm sewers or on the grass. The impact of such practices is largely unstudied.

A-56. HOUSEHOLD DUSTS

With centralized home heating and air conditioning becoming the rule in urban areas, the question rises as to the buildup of toxic substances within the closed home system. The amount of dust in home air (where air cleaners are unused) is significant. The effects of inhaling dusts from synthetic carpeting, draperies, clothing, sanding of drywall, etc., or vapors from cooking, aerosol cans, solvents, in cleaners, are largely unknown. Toxicological studies of such inhaled dusts are needed.

A-57. ECONOMIC TRENDS

Affluency will increase mobility and consumption of luxury items. Shorter work week will increase leisure pursuits and more recreational travel.

Increased shortages of resources will lead to the use of lower grade ores or of natural or virgin resources with substitutes. The former may require increased use of ore separation processes.

New foods and their production may increase organic loading of some resources. Hormonal additives will continue to be used (e.g., nitrogen toxing wheat, replacements for DES in meat).

There will be an increased concentration in space and time of food production.

Stressors

1. (1) Exotic metal alloys, plastics and fiberglass
2. (2) Waste streams from lower grade ores
3. (3) Food additives (i.e., hormones)
4. (4) New organic loading (e.g., from hydropinics or aquaculture)
5. (5) Pesticides replacing DDT

A-58. CRIME

Increased energy consumption for security, i.e., increased lighting, and increased energy consuming protective devices.

Development of new safety products which may have environmental implications (i.e., new materials for locks, new detection devices that are X-ray producing, or electromagnetic energy producing).

Increased probability of environmental disasters due to sabotage (e.g., petrochemical spills, fires, explosions - nuclear).

Increased potential for technologically sensitive crimes as technology becomes more sophisticated (e.g., upsetting electric, telephone, and gas delivery systems).

Stressors

1. (1) Sabotage
2. (2) Petrochemical spills
3. (3) Nuclear explosions
4. (4) Fire
5. (5) New energy demands

A-59. ASCENDING POWER GROUPS

Pressure to clean up pollution in minority ghetto areas (e.g., solid waste disposal, air quality).

Growing pressure to deal with occupational hazards. This applies to particulates in the air, fumes (e.g., fumes in enclosed spaces such as auto tunnels, painting parlors, ...).

Pollutants not now considered serious may be judged more serious by society in the future. The most likely case to grow as a problem is noise. A second general area is an upgrading of irritants to more serious consideration.

Increased consideration of problems of the elderly. This implies better recreation facilities for the elderly. It could mean better access into wilderness areas and more sedentary activities in parks.

Stressors

(1) Solid wastes
(2) Noise
(3) Occupational hazards
(4) Irritants

A-60. REVERSAL OF CORE CITY POPULATION DECLINE

Pollution build-up in the stagnant air of the urban "heat islands".

Powerful air drafts causing a safety hazard to people on the street below. Such intensive hot air drafts will have to be banned in the cities of the future to prevent changes in microclimates.

Concentration of population in the urban core (more high rise buildings) will result in a greater exposure of the population to air, water, and noise pollution. This will create further opposition to pollution in general in the urban core, and the case for "population dispersal" and "urban-rural balance" will be further strengthened. The megalopolis will have to be broken up by large green buffers around individual cities.

Stringent regulations will be imposed on the emission of asbestos, beryllium, and arsenic which are highly toxic. Also, the emissions of hydrochloric aicd and formaldehyde form strong carcinogens through synergism. These potential industrial pollutants will need immediate control.

Stressors

(1) Toxic metals
(2) Asbestos
(3) Heat islands
(4) Carcinogens
(5) Wastes disposal in high rise buildings

A-61. DEMOGRAPHY

Elderly persons may be more senstive to some pollutants, particularly air pollution. They may be less able to assimilate chemicals used in foods which may cause metabolic problems. Also, there may be an increase in environmental conditions as a cause of death because of the elimination of other causes (e.g., cure heart attacks and more people die of lung cancer caused by air pollution). This trend will increase the perceived seriousness of pollution.

An increase in solid waste due to increased use of packaging material to provide smaller unit of food.

Increased demand on natural resources by elder recreationists. There may be an increased acceptance of managed recreation areas resulting in less "true" wilderness.

Increased freedom of women to work out of the home. This implies more conveniences at home. more money to spend on family consumption and the use of more conveience foods.

Increased chemical and radiological treatment of diseases of elderly. These treatments will cause emissions in hospitals and other treatment centers.

Stressors

(1) Packaging materials

(2) Exposure to radiation
(3) Greater land use demands
(4) Food additives
(5) Drugs (increased use)

A-62. MEDICINE SCIENCE

Persons with artificial organs may be more sensitive to certain conditions of the environment. Controlled environments may be required for some individuals: other may be able to function normally in our society. However, pollution crises may be especially hazardous for those with artificial parts. Consequently, mortality and morbidity associated with pollution may increase.

The use of artificial organs and therapeutic drugs will increase mortality.

Hospitals will become more concerned with maintaining a "pure" in-house environment. This may be especially difficult for hospitals in highly polluted environments (e.g., downtown of large cities). While this problem may be particularly acute in hospitals it is pertinent to urban buildings in general. For example, air quality measurements in the Empire State Building have shown interior and exterior air to be essentially the same during rush hour.

There will be an increase in drugs in human waste.

Stressors

(1) Nontherapeutic drug use
(2) Human stress
(3) Controlled environments

A-63. GOVERNMENT

Regional and national waste disposal systems will greatly reduce pollution of air, water, and land in highly populated areas.

New chemicals and methods will have to be developed to abate or eliminate toxic materials from liquid waste to meet the "zero effluent discharge" requirements in 1985. For instance, a recent "bio-carbon" treatment process will remove certain toxic substances like copper, chromium, zinc, etc., from the petroleum refinery wastewaters. Such treatment systems, however, may raise the levels of salinity, total dissolved solids, etc., causing adverse water quality problems.

The energy recovery systems will help to ease the energy situation partially.

The resource recycling will ease a similar "resource scarcity" predicated by the National Comission on Materials Policy.

Increased local control on waste disposal as a result of Revenue Sharing Programs will result in inadequate pollution control at local levels. The industry will generate substitutes for banned products, thus making the pollution control very complex and unmanageable for the local officials.

Monitoring of earth resources (e.g., ERTS) may lead to invasion of privacy as a social issue.

Stressors

(1) Pollutants from new waste treatment schemes
(2) Increased salinity
(3) Inadequate control of exotic new chemical at local level.

A-64. TRANSPORTATION

New mass transit forms (BART, e.g.) will require study for new pollutant forms.

Fishing industry in Alaska (renewable resource) is concerned that they will be sacrificed because of spills associated with oil transport (nonrenewable resource) from Valdez by ship due to North Slope development.

Stressors

(1) Exhaust and other

(2) Oil spills

A-65. INTERNATIONAL

Dependency on friendly relations with Canada may effect policy decisions with respect to:

a. Water supply

b. The industrial uses of common waterways

c. Feasibility and wisdom of oil pipelines from Alaska through Canada.

Dependency on friendly relations with Mexico, Canada, France, and Turkey effects current approahces to incoming narcotics traffic.

Military preparedness for major wars involves the United States in further hardware production and basic physical sciences research. Energy consumption and further depletion of natural resources are tied to military policies.

Foreign ownership of American property may impinge on our freedom to enforce environmental legislation. Ownership of a sizable minority of stock may insert interests not consistent with the best interests of America.

Importation of Canadian waters to South California could be ecologically unsound. Increased salinity of the soil will damage agricultural productivity.

Prohibitions against disposal of nuclear and other industrial wastes in the high seas. These prohibitions are resulting from various international agreements. The result will be on shore disposal and storage of these wastes.

Stressors

(1) Narcotics

(2) Salinity

(3) Large volumes of waste

(4) Increase resource consumption.

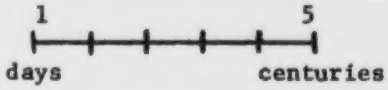
APPENDIX B

SELECTION OF MOST SERIOUS PROBLEMS

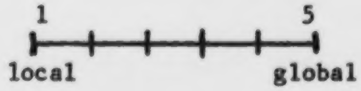
Ranking Factors

Initially a set of eight parameters were developed, each with a value scale of 1 to 5, for use in selecting and ranking the 10 most serious problems based on the data base of 65 problem statements. These factors and associated scales are described here.

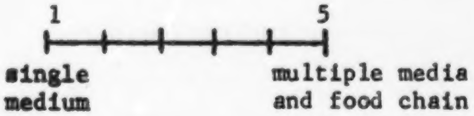
Persistence. On the basis of physical and/or chemical characteristics, the period during which a pollution problem might remain one of concern. For example, a reactive air pollutant might disappear as a problem within a few hours, whereas some radioactive wastes will retain their hazardous nature for thousands of years.



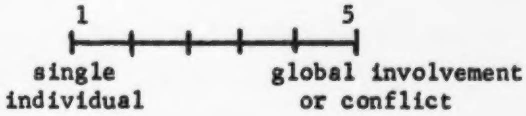
Mobility/Pervasiveness. Those problems which are highly mobile or stem from sources or activities which occur everywhere lie at a higher point on this scale than those which are isolated and/or stationary.



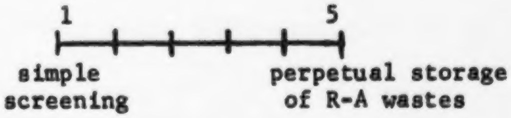
Relative Environmental/Ecological Complexity. The scale of this factor begins with a single environmental medium being involved in a problem. As more media are impacted, and the ecological chains are affected, the complexity increases.


1
5
single medium
multiple media and food chain

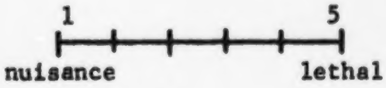
Relative Social/Political Complexity. This factor reflects the number and kinds of institutions involved in a problem. It is related to factors (2) and (3) above, in that a widespread problem will cross social and jurisdictional boundaries.


1
5
single individual
global involvement or conflict

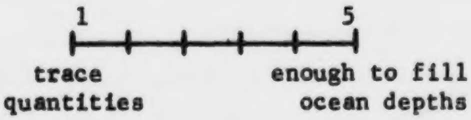
Relative Technological Complexity. As the sophistication of industrial production and associated side effects increases, both the cost and difficulty of control also tend to increase. This factor is intended to reflect that increasing complexity and the costs (including energy costs) of control.


1
5
simple screening
perpetual storage of R-A wastes

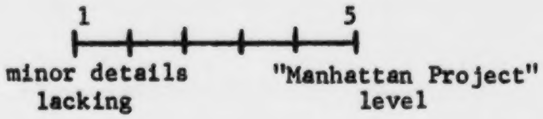
Physiological Risk. Based upon epidemiological and/or toxicological data, most stressors attributable to the pollution problems which have been identified can be assigned a position on the subjective risk scale.


1
5
nuisance
lethal

Bulk or Volume of Stressors. Those stressors produced by various pollution problems are sometimes described solely in terms of bulk or volume. Clearly, this factor alone provides little information about the relative severity of problems, although it is one factor which must be considered.



Research Needs. Several of the future problems with which we are concerned are poorly defined at present. In some cases, there may be circumstantial evidence of potential severity; in some cases, there is nothing more than conjecture upon which to base concern. This rating factor is intended to provide explicit allowance for those areas of uncertainty when ranking the potential seriousness of future problems.



Initial Ranking Method

In applying these factors to the 65 problem statements, a team of four professionals, each broadly acquainted with environmental issues, was assembled. The problem statements were quickly separated into two classes by consensus of the team, viz.: (1) problems important enough for detailed ranking using the ranking factors, and (2) relatively unimportant as a single serious problem. (Note: the societal statements were excluded on the basis of insufficient specificity for ranking purposes.) On this basis 23 of the original set were selected for detailed ranking. The values assigned to each parameter were totalled for each problem statement. Each statement was ranked individually by each team member. A score for each problem so ranked was computed as follows:

(1) Each person's ranked problems were ordered from highest to lowest (see Columns 2 through 4 of Table B-1).

(2) A numerical value equal to the order of ranking was assigned to each problem statement for each team member's rankings.

(3) Where two or more problems ranked equal, an average value was computed, e.g., Problems A-23, A-26, and A-50 for Team Member A each received a value of 3 points since they were in the 2, 3, and 4 positions $[(2 + 3 + 4) \div 3]$

(4) The individual (team) values were totalled for the 4 team members to give an overall problem statement score.

(5) The problem statements were reordered from low to highest as shown in the second last column of Table B-1.

(6) The problem statement rankings were then employed to construct a tentative listing of 10 serious problems.

Examination of the rankings (see listing Table B-2) permitted the construction of a list of the 10 most serious problems. This was done through (1) combination of related problem statements (e.g., numbers A-11 Automotive Exhaust and A-12, Catalytic Convertors for Autos which ranked 7th and 5th respectively), (2) discussions with the Project Officer (EPA) and (3) further review of all 65 problem statements.

Selected 10 Most Serious

Following are the ten most serious problems with a brief discussion of the scope and relationship to the problem statements from whence they were derived.

TABLE B-1. PROBLEM STATEMENT RANKINGS

	Team Member					
Order	A	B	C	D	Overall Ranking Order*	Numerical Score
1	A- 9	A-50	A-26	A- 9*	A- 9	10.5
2	A-23*	A- 9	A-23*	A-12*	A-23	15.0
3	A-26*	A- 2*	A-50*	A- 2+	A-26	20.5
4	A-50*	A-23*	A-13*	A-11+	A-50	21.5
5	A- 4	A-29*	A- 9+	A-23	A-12	29.5
6	A-24	A-12+	A-11+	A- 1*	A- 2	31.5
7	A- 1*	A-26+	A-12+	A- 8*	A-11	37.5
8	A- 2*	A- 1*	A-15	A-43*	A-15	39.5
9	A-43*	A- 6*	A-43*	A-10+	A- 1	42.0
10	A-15*	A-11*	A- 4*	A-26+	A-43	44.0
11	A-29	A- 8+	A-37*	A-15+	A-29	44.5
12	A- 3*	A-13+	A- 8+	A- 3*	A- 8	48.0
13	A-10*	A-37+	A-29+	A- 6*	A-24	50.0
14	A- 8+	A-24+	A-24	A-37+	A- 4	50.5
15	A-12+	A-15+	A- 2*	A-50+	A-37	52.5
16	A-16+	A-16*	A-16*	A- 4*	A-13	54.0
17	A-37+	A- 3*	A- 1+	A-29*	A- 6	58.0
18	A- 6*	A- 4*	A- 6+	A-24*	A- 3	63.5
19	A-11*	A-21*	A- 3*	A-13	A-10	66.5
20	A-13*	A-43*	A- 5*	A-16	A-16	69.5
21	A-22	A- 5*	A-22*	A-21	A- 5	83.5
22	A-21	A-10	A-10	A- 5	A-21	84.5
23	A- 5	A-22	A-21	A-22	A-22	87.0

*,+ These symbols indicate groupings of problems that ranked numerically equal.

* See discussions of how order was numerically determined in text of report.

TABLE B-2. LIST OF RANKED STATEMENTS

Overall Ranking Order	Number	Title
1	A- 9	Fine Particulates in Air
2	A-23	Inorganic Toxic Contaminants
3	A-26	Chlorinated Hydrocarbons, Pesticides, Herbicides, and Fungicides
4	A-50	Radioactive Wastes
5	A-12	Catalytic Convertors for Autos
6	A- 2	Sludges, Liquid, and Solid Residues from Pollution Control
7	A-11	Automotive Exhaust
8	A-15	Drinking Water Treatment
9	A- 1	Disposal of Secondary Treatment Sludges
10	A-43	Advanced Waste Water Treatment
11	A-29	Carcinogens
12	A- 8	Acid Mine Drainage
13	A-24	Irrigation Practices
14	A- 4	Effects from Dredging
15	A-37	New Landfill Technology
16	A-13	Nondegraded Organics from Secondary Treatment
17	A- 6	Coal Cleaning Residues
18	A- 3	Impacts from Flue Gas Treatment
19	A-10	Toxic Substances in Recycled Animal Waste
20	A-16	Disposal of Waste Oils from Oil Spills and Other Sources
21	A- 5	Oil Well and Other Waste Brines
22	A-21	Noise
23	A-22	Microwave Radiation

*,+ These symbols indicate groupings of problems that ranked numerically equal.

* See discussions of how order was numerically determined in text of report.

Fine Particulates. This problem (see A-9) ranks high in terms of (a) direct health effects on man, (b) a multiplicity of sources, (c) the relative persistence and pervasiveness of fine particulates once they are emitted, and (4) the difficulty of control before, and mitigation after, emission. Even with the best available control technology, which will result in a significant reduction in total emissions, a major fine particle fraction will be emitted. The health hazard can be quite out of proportion to the mass involved, whether the particulates are chemically active or inert.

Trace Element (Metal) Contaminants. This problem, discussed explicitly in A-23, is an aspect of many of the problem statements (see A-1, A-2, A-3, A-11, etc.). This is an all media problem which can have severe consequences if uncontrolled. As with fine particulates, control is difficult to exercise once the elements are well dispersed along a pathway. Major sources of emissions are known and can be expected to be brought under control, although trace elements are a component of the fine particulate problem wherein even the best available control apparently will not be adequate. Discrimination between acceptable and hazardous levels in terms of human health or biosphere effects needs to be developed through research. The biological conversion of certain elements, notably metals, to even more toxic organic forms further complicates the problem.

Proliferating Hazardous and Toxic Chemicals. Public concern over hazardous chemicals like DDT, hexachlorobenzene, dioxin, and numerous other chemical substances which have crept into the environment through technological advancement is at a high level. Recent newly identified toxic contaminants in air, water, and solid waste effluents from industrial, agricultural, and municipal sources suggests that the magnitude of the problem is greater than expected. Urban pesticide use and street runoff are now being recognized as problems along with agricultural sources. Unless some means for the early detection, assessment, warning, and application of corrective measures can be found, such substances will continue to proliferate in the environment. (See A-10, A-13, A-26, A-28, A-29, A-30, A-45, A-46, and A-54).

Critical Radiation Problems. Although radioactive releases from nuclear processes are widely recognized as a serious environmental problem, they are only a part of the total radiation problem and are, at current levels of release, less significant than other forms of electromagnetic radiation. Attention must also be focused upon radiation from accelerating use of medical, dental, and industrial X-ray devices (even though direct health effects are the responsibility of OSHA-HEW, EPA does have an ancillary concern regarding environmental pollution), lasers, television, radar, and all forms of microwave devices. Potentially serious environmental hazards to physical and psychological health are escalating as man exposes himself and his environment to greater intensities of radiation over parts of the electromagnetic spectrum against which evolution has provided little defense. (See A-22, A-50, A-51, A-85.)

Disposal of Waste Sludges, Liquids, and Solid Residues. Many of the problem statements (A-1 to A-7, A-37) bear on this general problem which is in brief: what to do with the enormous volumes of frequently contaminated and hazardous residues that will be generated as a consequence of pollution control efforts. The options are diminishing with respect to traditional disposal outlets; namely, ocean dumping, deep-well injection, lagoons, open dumps, land spreading, etc. In the short term (5-10 years) it seems apparent that the controlled land disposal route will be attempted to a greater extent. Information needs exist with respect to environmentally acceptable practice, especially for hazardous wastes.

Emissions from New Autmotive Fuels, Additives, and Control Devices. This is a major problem of the next 5 to 10 years during which millions of autmobiles are slated to be serviced with new gasoline formulations and blends, fitted with catalytic exhaust convertors, and built with new low-polluting engines (see A-11, A-12). The removal of lead; the substitution of manganese for lead; the several hundred new fuel additives; the manufacture, operation (especially under poisoned or aged conditions), and disposal of heavy metal catalyst based convertors; all have environmental consequences that will require more study. This is a national problem and is very directly tied to human health.

Expanding Drinking Water Contamination. It is becoming recognized that past methods of potable water treatment have been directed at a relatively narrow group of contaminants, while at the same time the number and type of substances entering water supply sources have been increasing as a consequence of man's activities. The search for substances with deleterious health effects in drinking water supplies is expected to proceed with more intensity because, like food, water is a direct and essential input to the human body. The candidate contaminants include virtually every stressor discussed so far; i.e., heavy metals, organics, biologicals, radioactive elements.

Geophysical Modification of the Earth. The key thrust of this future pollution problem is detrimental effects arising from physical disturbances of the earth generated by man. These include acid mine drainage, strip mining, dredging, siltation, erosion, disturbance of surface cover, underground explosives, modification of stream channels, diversion of water flows, and water impoundments. These gross interventions in the biosphere become more of a problem as man increases his total output, processes more tons of material per unit of output, uses lower grades of ore, and otherwise increases his throughput of materials. As this throughput increases, the reduction in available non-renewable resources reduces man's alternatives and also increases risks of serious environmental upsets from modifications of ever shrinking resources. Acceptable trade-offs between man's activities and the environment have yet to be determined (see A-4, A-8, A-16, A-17, A-18, A-19, A-20, A-35, A-42, A-48).

Irrigation (Impoundment) Practices. Large areas of the U.S. employ irrigation practices to permit use of arid soils for agricultural purposes. The buildup of salts, heavy metals, alkalis, and acids in soil threatens water supplies of nearby communities and with time decreases soil productivity. The use of impoundments to collect water for irrigation purposes results in some severe environmental imbalances. Control is difficult. The need for such practices is directly related to U.S. food needs.

Impacts of New Energy Initiatives. The current concern over energy sources and supply will result in many new initiatives within the next 5-10 years. The development of new energy extraction technologies (coal gasification, liquefaction, geothermal, nuclear, solar and MHD power; coal cleaning and desulfurization; oil shale and tar sands processes) are in an early stage. Consequently, it is logical to examine these developments now with respect to their eventual adverse environmental impacts. These impacts include thermal discharges, radioactive waste disposal, heavy metal and toxic organic emissions, increased strip mining, ever greater volumes of coal residues, washes, ash and acid mine drainage (see A-6, A-8, A-14, A-31, A-35, A-49, A-50).

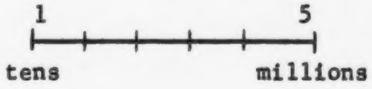
Selection of 3 Most Serious Problems

The preceding identified problems were subjected to further ranking based on (1) an additional ranking factor, (2) examination of the relative weights to be assigned to each ranking factor, and (3) study by a larger group of Battelle-Columbus professionals.

Added Ranking Factor

One additional factor was added at this point, defined as follows.

Number of People Affected. Although this factor might be related to Mobility/Pervasiveness, it is intended to reflect the typical location of the problems in question. For example, an urban-oriented source obviously affects more people than does a remote mine or other rural operation.



Weighting

No weighting of the initial eight ranking parameters was employed in selecting the 10 most serious problems. Since it was felt this could be a serious omission, weights were developed at this point in the program as a preliminary to prioritizing the 10 problems.

The method used for ranking the factors was the procedure of paired comparisons. A panel was made up of 9 persons, in the physical, life, and social sciences, all of whom are involved in environmental research. Two iterations were used to approach a group consensus, with the results of the first iteration being made available to the panel prior to the second ranking. This system is known as the Delphi Technique. The resulting factors and their relative weights are as follows:

Criteria	Weight
Nature of the Substance	(47)
1. Physiological risk (toxicity)	14
2. Persistence	13
3. Mobility/pervasiveness	11
4. Bulk or volume of substance	9
Nature of the Problem	(53)
1. Number of people affected	12
2. Relative environmental/ecological complexity	11
3. Relative technological complexity	10
4. Relative social/political complexity	10
5. Research needs	10
TOTAL	100

It is noted that one of the results of this exercise was the recognition that the ranking factors could be divided into two groupings based upon (1) the nature of the substance(s) and, (2) the nature of the problem. Since the 10 problems are not limited to a single substance, the person ranking must make a judgment based on his perception of the various types of substances involved and their relative importance. Obviously, such intangibilities tend to argue against the validity of the ranking factors applied to what are essentially broad problem areas. Nevertheless, it is felt this approach is one of the few attempts being made today to avoid totally subjective (and unavoidably biased) priority setting.

Additional work on development of appropriate criteria for making selections among many alternative pollution problems is needed. Further effort to refine the factors was not justifiable in this program.

Another outcome of this weighting effort was the recognition that the weights did not vary appreciably over the nine factors. In fact, it was felt that little merit in applying the weights would result and, thus, the factors were given equal weight in prioritizing the 10 problems.

Priority Ranking of 10 Problems

Application of the expanded list of ranking factors to the 10 most serious problem areas was done utilizing a dozen Battelle-Columbus professionals with the following result:

Ranking	Problem
1	Impacts of New Energy Initiatives
2	Geophysical Modifications of the Earth
3	Trace Element (Metal) Contaminants
4	Proliferating Hazardous and Toxic Chemicals
5	Emissions from New Automotive Fuels, Additives and Control Devices
6,7	Disposal of Waste Sludges, Liquids and Solid Residues
6,7	Critical Radiation Problems
8	Fine Particulates
9	Expanding Drinking Water Contamination
10	Irrigation (Impoundment) Practices

☆U.S. GOVERNMENT PRINTING OFFICE: 1974 546-317/293 1-3